THE SOIL SCIENCE SOCIETY OF FLORIDA

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PROCEEDINGS VOLUME XI 1951

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Eleventh Annual Meeting of the Society
George Washington Hotel
West Palm Beach
October 29 and 30
Field Inspection Trip, Everglades Area
October 31, 1951

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1952

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ACKNOWLEDGMENTS

The Executive Committee, in behalf of the entire membership of the Society desires to take this opportunity to thank the officials and the staff of the George Washington Hotel for their splendid hospitality and tireless efforts in making the meetings a success; also the officials of the Central and Southern Florida Flood Control District; and of the Florida State Geological Survey, Tallahassee; and of the Jacksonville Office of the Corps of Engineers, Department of the Army, for their fine assistance with the Panel Discussion of Water Conservation; also the officials of the Everglades Experiment Station, of Newport Industries, Inc., and of American Kenaf and Ramie Corporation for their splendid help in connection with the fiber crop field trip and with the first meeting of the Committee set up by the U. S. Department of Agriculture to develop and define a system of marketing grades for kenaf, the proposed soft fiber substitute for jute to be grown in the Western Hemisphere.

We wish also to express our particular appreciation to Mr. Walter R. Guthrie, of the Lehigh Spinning Company, Allentown, Pa., for the generous amount of time he gave us and the fine part he took in the program and to the following officials from Washington, D. C., and elsewhere for the special effort they made to be with us: Dr. Arthur G. Peterson, Chief, Textile, Forest and Agricultural Products Division, Office of Materials, Munitions Board; Dr. Charles W. Schoffstall, Chief, Fibers Branch, Textile Division, National Production Authority; Mr. E. D. Bell, Deputy Director, Cotton Branch, Production and Marketing Administration, U.S.D.A. and his Associates Mr. Wilson C. Tucker and Mr. H. C. Slade; and Messrs. George R. Boyd and Elton G. Nelson, Bureau Plant Industry, Soils and Agr. Engineering, U.S.D.A.; likewise to Mr. N. N. Mayo, representing the Commissioner of Agriculture, Honorable Nathan Mayo; Dr. Herman Gunter, State Geologist from Tallahassee; Col. A. G. Matthews, Chief Engineer, Div. Water Surveys and Research State Board of Conservation, Tallahassee; Dr. Wm. L. Lett, Secretary, National Cotton Council, Memphis; Mr. George F. Quimby, Secretary-Treasurer of Soft Fiber Manufacturer's Institute, New York City; Col. George D. Green, President, Southern States Bag Company, Jacksonville, and to Mr. Alexander Low, N. A. Rep. Indian Jute Mills Assoc., Inc., New York City.

Finally, we want to express our sincere pleasure for having had with us during these meetings a number of foreign members and friends, notably a very fine delegation from Cuba, among which Mr. Jose A. Perez represented the Minister of Agriculture; Mr. Luis A. Sanjenis, Second V. P. and Ing. Manuel Suarez-Carreño, Treasurer, respectively, of the Asociacion Nacional de Casecheros de Kenaf de Cuba were this organization's representatives; and Ing. Julian B. Acuña represented Banco de Fomento e Industrial de Cuba. Messrs. Federico Poey and Joe E. Walker of Havana and Eduardo Lopez of Guanabacoa, Cuba, also were in attendance; and Mr. Duane W. Clark of the Office of Foreign Agricultural Relations, U.S.D.A., Washington, D. C., and his co-workers from Pakistan, Messrs. Wadihul Islam, MD. T. Hussian and A. F. MD. Hafizar Rahman. It is of course a particular pleasure to record the attendance of our good friend and fine cooperator in the fiber work, Mr. R. A. Colyer of Sydney, Australia and Raboul, New Guinea.

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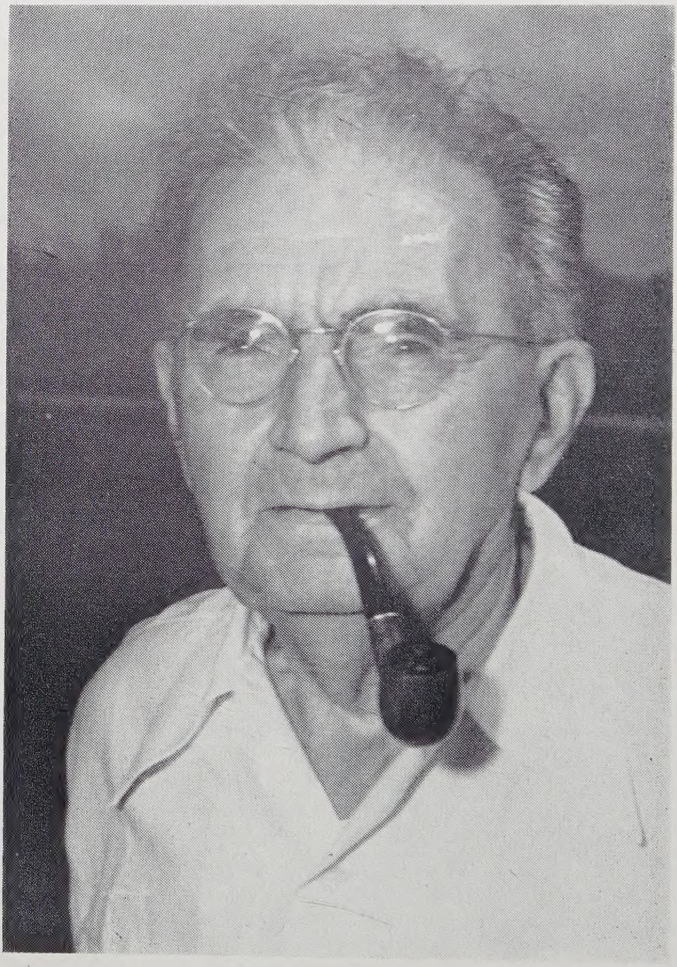


CHARLES R. SHORT

DEDICATION

CHARLES R. SHORT

Charles R. Short was born in London, Ontario, Canada in 1871, where he attended school and then served as an apprentice machinist and tool maker. He first entered the United States in 1899 and worked in Detroit, Michigan; Cleveland, Ohio; Erie, Pennsylvania and New Haven, Connecticut. Returning to London, Canada in 1891, he married Mary Adaline Clark. To them four children were born.

From 1891 to 1906 Mr. Short was Chief Engineer, Motor Division, Canada Cycle and Motor Company, located at Toronto Junction, Ontario, Canada. A practical aluminum body ice skate was developed during this period. Following his return to the United States in 1906 he was Chief Engineer, Standard Gas and Electric Company, Philadelphia, Pennsylvania until 1910. During this time he developed the auto motor electric starter and equipped test cars for Cadillac, Peerless, Pierce Arrow and Stevens Doyrea.

From 1910 to 1912 he was Electrical Engineer for Packard Electric Motor Company, St. Catherines, Ontario, Canada. While employed there he developed the auto electric starter for the Canada Cycle and Motor Company, Toronto.

Returning to Detroit in 1912 he formed the Short and Wilson Tool and Machine Company, and continued in this work until 1916 when he became Chief Engineer, Northway Motor Division, General Motors. He continued in this position until 1922 when he was made Chief Engineer, General Motors Research in which position he remained until 1931 when he retired. During these years there was developed, among innumerable other improvements to automotive equipment in the General Motors field, the "V"-Belt.

Following his retirement in 1931 from General Motors Research Mr. Short moved to Clermont, Lake County, Florida, where he developed the Florida Industrial Laboratory. Since the establishment of this laboratory there has been developed in it a dehydrating machine for the preparation of sawgrass peat for market; many projects in connection with the local diatomite deposits including a remarkable "all-weather", salt shaker; a hyacinth cutter for the U. S. Engineer Corps, Jacksonville and decorticating and degumming machines for bast fibers. He also developed a Citrus Research Grove to assist with the solution of some of the nutritional problems of this important industry in Florida at about the time they had arrived at their most critical level in the middle to late thirties; and he is president of the Citizens Bank of Clermont.

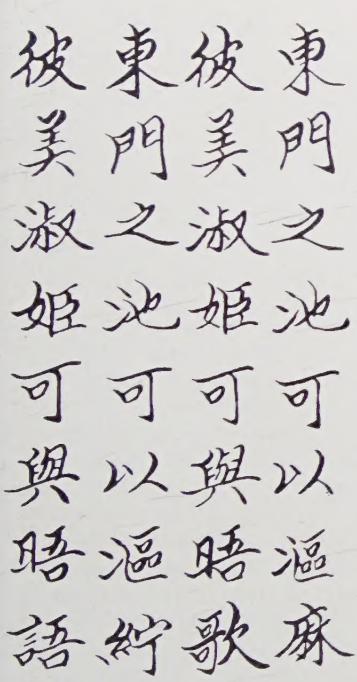
It is regrettable that Mr. Short's attendance upon these meetings was prevented by the recurrence of an unfortunate illness which has given him considerable trouble during recent years and which required hospitalization at this very time and a serious operation. Fortunately, he had again quite fully recovered by the time this Proceedings was ready for the press and was back again in the shop as active as ever on the development of equipment and processes for the decortication and degumming of bast-fibered crops (ramie and kenaf), a project we are inclined to believe has been the "apple of his eye" since about 1944.

Miss Bernice Montgomery standing beside an exhibit of all-ramie fabrics which she arranged at the time of the meeting. The small parasol which she is holding is of Japanese design and construction, the cover being, of course, RAMIE.

RAMIE CULTURE IN THE FAR EAST

BERNICE MONTGOMERY *

This Chinese poem, from the Book of Odes, contains the oldest known reference to the fiber which we now call ramie. The poem is at least 2,500 years old, perhaps older. The poet tells of a beautiful lady and compares her to the water in the moat at the East Gate of the city. In order to describe how shining and clear the water is he says it is fit for steeping ramie. It is interesting to note that the character denoting the fiber "ramie" is similar to that used for silk. In other words the above character for ramie represents a beautiful, lustrous fabric made of fiber from plants of the genus Boehmeria; the character for silk represents a beautiful, lustrous fabric made from fiber spun by the silk worm.



This Poem, in Ancient Chinese, makes the first known reference to Ramie in the literature of the world. Very kindly reproduced from the original by Joseph En-pao Wang, Division of Orientalia, Library of Congress, Washington.

Many people in America think of ramie as being principally Chinese in origin. Actually, according to Oriental legend, ramie plants first grew and the fiber was first used on the southeastern slopes and foothills of the Himalayas, especially down through the area which is now Malay and part of Indonesia. The word "ramie" is the Anglicized form of the ancient Malayan word for the plant and its fiber.

People on the Indo-Pakistan subcontinent have also been growing and processing ramie fiber for a long time. It is quite possible that the ramie fabrics found on some of the Egyptian mummies of the pre-dynastic period (3300 B. C. to 5000 B. C.) were imported by the Egyptians from India. Ramie fabrics are mentioned in ancient Vedic literature. Reference to ramie is found in the drama "Sacantala" by Kalidassa, generally supposed to have been written about 100 B.C.

Much of the ramie fiber used in the Far Eastern areas is obtained from plants growing in a wild state. Methods of preparation vary widely though all involve essentially the same principles. Everyone will recall reading varying descriptions of these processes, each description purporting to be the correct one. Actually it is one of those happy situations where practically every one is right. Lack of transportation and communication in these areas have resulted in each small area developing

* Marketing Consultant, Fifth Avenue Hotel, New York City.

its own way of processsing ramie. In most cases this way has been maintained without change for many generations.

Basically, the processing involves first, removal of bark with fiber attached, by peeling; stalks may or may not be soaked in water before this peeling takes place. In some areas the peeled bark, with fiber attached, is dried and later soaked in water, hot or cold, fresh or salt, before the fiber is freed from the bark. This latter method is generally used in the northern regions where the winter season with little farm activity allows time for processing of ramie fiber during this period of the year.

Instruments used to free the fiber from the bark, by scraping, range from clam shells to specially prepared pieces of bamboo and iron knives, depending on local customs and equipment available. A protector of some sort is wrapped around the thumb, the scraping instrument held in the palm of the hand and the fiber then drawn between the edge of the scraper and the thumb. The amount of scraping done, that is, the degree of separation of the fiber from the bark and from the gums and waxes, depends largely upon the intended end use of the fiber. Obviously, if the fiber is to be made into very fine yarns, a great deal of scraping will be required, that intended for coarse yarns does not require much scraping.

China for many years has grown most of the world's supply of commercial ramie fiber, the total production averaging about 75,000 tons annually, pre-World War II. This country's exports averaged about 25,000 tons annually during the same period. Methods of cultivation and processing used in China are generally primitive. Cultivation and harvesting are done with hand labor. Fiber removal is also done by hand, though in a very few instances a small machine decorticator may be used. Degumming is done by alternate soaking and hand scraping; in some areas the yarn or fabric is also boiled in a weak solution of caustic soda, which removes some of the gum and acts as a bleaching agent.

Chinese ramie fiber intended for commercial export is often bleached with charcoal or sulfur fumes after it has been separated from the bark of the plant. This is the so-called "white" ramie of commerce. The terms "white" and "green" used in this connection should not be confused with the terms "white bark" and "green bark" used in connection with ramie plants grown in the Far East. The last two terms apply to varieties of *Boehmeria nivea* and not to the decorticated fiber.

Ramie has apparently been grown in the Philippines since prehistoric times. It was first cultivated on a commercial scale during the 1930's in the southern island of Mindanao, especially on the land owned by Japanese capital. Production was, of course, disrupted during World War II. Post-war production has been slow in resumption because channels of trade have been re-established only slowly. It is expected, however, on the basis of present plantings and plans, that ramie fiber protion in the Philippines Islands will increase markedly in the near future.

Utilization of ramie is also found on most of the islands of the Pacific which are adjacent to or near the coast of the Asiatic continent. This includes Indonesia, where "tali rami", a kind of twine used for fishing nets, excited the imaginations of the Dutch and the English East India Companies and later the traders of the nineteenth century, especially during the periods when the Napoleonic Wars and later the Crimean War

disrupted the supply of hemp cordage fiber from Russia. A small qauntity of ramie fiber has been exported from time to time from the Islands of Indonesia to Europe.

Japan has cultivated ramie plants and used the fiber since prehistoric times. At one time, about 300 years ago, the armies of the Shoguns were clothed in uniforms made from ramie. Primitive hand methods of cultivation and hand processing may still be found in the mountain areas of Japan. Japanese ramie is better known, however, as a commercial product.

Only about 1,000 tons of fiber can be grown in Japan annually because of the pressing need for food crops. The mills of Japan, however, need about 10,000 tons annually and in times past imported most of this from China. Presently imports are coming from many parts of the world.

In a few moments, Mr. Averill, the projectionist, will run a film showing ramie fiber processing on a commercial scale in Japan. The methods used in the Japanese mills are approximately the same as those used in the mills in Germany and other European countries.

This picture was made with the cooperation of the world's largest ramie mills which are located in Japan. The Hard and Bast Fibers Trade Association of Japan assisted in making arrangements, as did also the officials of the Prefectures in Japan where the pictures were made.

The actual photography was done by the U. S. Army Signal Corps. Cpl. J. C. Carey and Pfc. David McLean were the photographers. Any rough spots and shortcomings in the picture are to be attributed to me since responsibility for planning and direction was mine.

The showing of the 30-minute movie that is to follow and which will give many details of the culture and processing of ramie in Japan was cleared especially and exclusively for this meeting by the Office of Public Information of the U. S. Department of Defense.

Editor's Note: A group of 18 frames was selected from this film and these, with the additional photo (No. 3) on harvesting, from another source, constitute the series of figures that follows. It is hoped that the rather full legends which Miss Montgomery has provided for these pictures will assist very materially in giving those who did not see the film a good idea of the conditions of cultivation and processing of ramie in the Far East which she has studied for a number of years.

Figure 1.—*Preparing the Soil.* The land is first deep-plowed or turned by hand with a mattock similar to the one shown in the picture. It is then well pulverized by a harrow, usually wooden, which may be drawn by horse or pulled by hand. Trenches 7 to 8 inches deep, are then made with the mattock, and fertilizer (compost, barnyard manure and commercial fertilizer) mixed with soil is turned back into the trench from the surface ridges to a depth of about 2 inches.

Figure 2.—*Planting.* Ramie may be propagated in 3 ways: by seed, by rooting cut pieces of the mature stalk and by cut pieces of the root system, which are known as rhizomes and sometimes as "reproductive roots." The last named is the most satisfactory and widely used. In the picture, cut pieces of rhizomes are being placed in the trench. Pieces are about 4 to 5 inches long and care is taken to have each piece with two or three buds. Soil is then turned into the trench, with the mattock, to cover the rhizomes. Plants begin to appear above ground 7 to 10 days after planting. The field is then inspected and any dead pieces of rhizomes replaced.

Figure 3.—*Harvesting.* Stalks are cut by hand with a sickle. Plantings, in the latitude of Kyushu, Japan, require from 1 to 2 years for the root system to spread out and become well-established. Fields are weeded by hand until roots spread out to provide enough stalks to shade the ground. Cultivation of plants and application of fertilizer also is by hand, at regular intervals. The first stalks sent up are cut when they reach a height of 3 to 4 feet, and allowed to remain on the ground. The cutting encourages the root system to spread out. Allowing stalks to remain on the ground also helps to prevent weeds, conserve moisture, and enrich the soil. This preliminary cutting is usually done twice during the first year. The third growth, if conditions have been favorable, can be cut for fiber extraction, though yield per acre will be low. By the second year the root system will be sufficiently established to provide satisfactory yield of fiber at 60 day intervals during the warm growing season. In Kynshu, 3 crops may be harvested per year, resulting in an average of 1,100 pounds of fiber per acre, with higher yields from fields that receive good care, adequate fertilization and have a favorable growing season. Plants in the picture are 2 years old.

Figure 4.—*Transporting Stalks to Decorticator.* The decorticator, a machine for extracting the fiber from the stalk, is portable and is moved to a place near the field where harvesting is done. Stalks are moved to the decorticator on small, two-wheeled carts. Note that stalks have been placed on cart with root ends even.

Figure 5.—*Decortication.* This operation removes the fiber from the stalk. To obtain the highest quality and the greatest quantity of fiber, stalks should be run through the decorticator as soon as possible after harvesting.

Ramie fiber is located in bast bundles that occur in the outer part of the stem which completely surrounds the central woody portion, just under the outer bark and running the full length of the stalk. The bundles are held in place by gummy and waxy substances and by the cellular tissue around them. The object of decortication is to remove these bundles of fiber from the stalk cleanly and efficiently and with their length intact. Machines used for this purpose all operate on the same basic principle, which consists, essentially, of crushing stalk between rollers and then bringing it into contact with blades set in the outer circumference of a rotating wheel which scrape bark and woody portions of stalk from fiber.

The machine in the picture was patented in Japan in 1947 and is run by a 3 h.p. motor. Average production is about 400 to 450 pounds of fiber, dried basis, per 8-hour day; skilled operators produce more. The full length of the stalk is decorticated on a continuous basis, no defoliation, topping or butting of stalk being required before decortication.

Decorticated fiber may be seen in the center of the picture, coming from underneath the machine. It is caught by the worker seated on the ground just to the left and beyond the workman who is feeding the machine and hung over the bamboo pole placed on pegs extending from two upright poles see lower left corner of picture. The pieces of bark, woody material, and leaves fall to the ground below the machine. A pile of this waste material may be seen in the picture. The waste is carefully saved and used as compost for fertilizing the crop. Use of this material reduces to a minimum the amount of nitrogen fertilizer needed.

When fiber has been hung all the way across the pole, another worker removes the full pole and replaces it from a pile, the ends of which may be seen on the left-hand side of the picture. The filled pole is hung on an upright bamboo frame

Figure 1

Figure 2

Figure 3

Figure 4

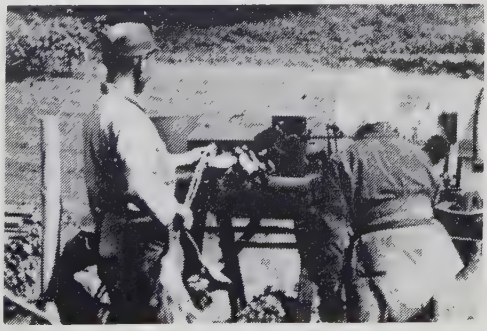


Figure 5

and the fiber is allowed to dry in the open air and sunshine. Drying the ramie ribbons in the sun is considered important as a more lustrous, stronger fiber results than if air-dried in the shade.

Figure 6.—*Brushing.* After the decorticated fiber is thoroughly dry it is brushed to remove any bits of bark and woody material remaining. The brushing machine, also patented in Japan in 1947, is operated by a 2 h.p. motor. Its average production is 250 to 300 pounds of brushed fiber per 8-hour day.

Fiber is brushed by bringing it into contact with very coarse combs set into the outer circumference of a rotating wheel. Note clean, smooth appearance of fiber on the table at the left side of the picture in comparison with fiber on table on the right. Brushed fiber is baled and sent to the mills.

Figure 7.—*Degumming—First Step.* The purpose of the degumming process is to remove the gums and waxes which still remain on the fiber. At this stage, the fiber is in strands or ribbons that are made up of the bast bundles of fiber which run the full length of the original stalks. Each strand is made up of many individual fibers, which may range in length from ½ to 20 inches and usually average 5 to 6 inches. Removing the gums and waxes frees the individual fibers so they may be better sorted, combed, and twisted during the spinning operations. Ramie is the only bast fiber which can be separated into individual fibers before any yarn preparation or spinning operation takes place. The unusual length of the individual fibers makes this possible and practical.

When the bales of fiber reach the mill, they are opened and the fiber inspected. It is then tied in small bundles, using one end of a strand of fiber. These small bundles are tossed onto a scale and when the specified weight is reached, are placed in a wire basket for the first step in the degumming process.

In the picture, the wire basket loaded with ramie fiber is being moved toward the first step in the actual degumming process. This consists of placing the basket and its contained fiber in a clean, empty vat and covering it with clear, cold water for about 24 hours or until the fiber is thoroughly re-wetted. This is important to allow thorough penetration of the degumming solution, into which basket of fiber is next immersed.

Figure 8.—*Degumming—Second Step.* The degumming solution, into which the basket of fiber is immersed, consists of a water solution of caustic soda, the amount of caustic soda depending upon the quality of fiber and amount of gums and waxes it contains. The solution is kept at boiling point and the fiber remains in it about 4 hours, again depending upon quality of fiber and amount of gums and waxes on it. Agitation, during the boiling, is by hand with a wooden pole, as shown in the picture. Care must be used in stirring fiber to avoid tangling.

Properly done, boiling in the degumming solution will soften and largely remove gums and waxes and leave fiber clean with strength, luster, and other desirable qualities intact.

After boiling, fiber may or may not be rinsed in a solution containing a chemical to neutralize caustic soda, depending upon procedure at mill. Sometimes mechanical agitation and plain water are used for neutralizing.

Figure 9.—*Washing.* After boiling and neutralizing, fiber, while still wet, is washed thoroughly in clean water to remove any gum and wax which has been loosened but not removed during the preceding operations.

Figure 10.—*Drying Degummed Fiber.* After washing, the fiber is soaked in an emulsion of oil and water and hung over bamboo poles. These are suspended from open-air racks until fiber is dried.

Figure 11.—*Sorting Fiber by Lengths, First Step.* After drying, degummed fiber is run through a softening machine, sprayed lightly with an emulsion of oil and water and aged in a humidifying room for about a week. Fiber is then taken to fiber preparation room to be sorted by lengths.

The first machine, into which fiber is being fed in the picture, is called a Large Filling Engine. Fiber is given first combing on this machine, being caught onto a large drum at the back of the machine by means of teeth placed in single rows at intervals across the surface of the drum. Fiber is then cut into 12 inch lengths and combed lightly again while still caught on these teeth. It is removed from the drum by placing small willow sticks across the center of the 12 inch lengths and doubling the fiber over the sticks. At this stage fiber is termed "fringe."

Figure 6

Figure 7

Figure 8

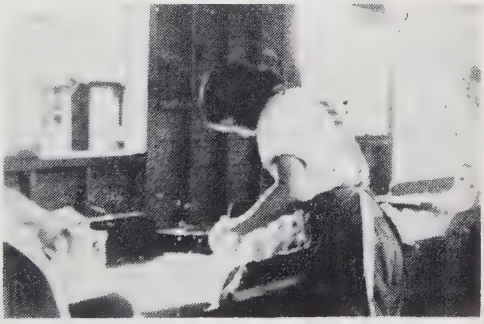


Figure 9

Figure 10

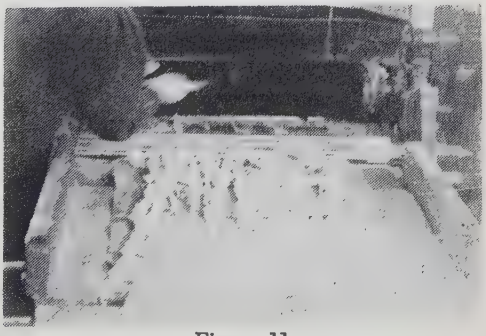


Figure 11

Figure 12.—*Sorting Fiber by Lengths, Second Step.* The fringe, i.e., sticks with fiber over them, is taken to a large machine called a dressing frame. Sticks with fiber over them are locked into place at the top of a large, slowly revolving drum by an operator who stands on a high platform in back of the machine. Ends of fringes, just after they have been locked into place, may be seen on the upper part of the drum in the picture. As the drum revolves the ends of the fringes are brought into contact with rolls covered with wire teeth, which are located under the drum and which comb the fiber, removing the shorter lengths.

When the drum has made a complete revolution, the operator reverses the fringe, locking it into place again by placing one end between two wooden slats. The willow sticks are allowed to hang loosely against the length of the fiber. They are removed by a second operator when the reversed fringe reaches the front of the machine. As the drum revolves, the length of the fringe is brought against the combing rolls. In the picture, reversed fringe, hanging to its full length, may be seen on the lower part of the drum as it is moving down toward the combing roll. The operator standing to the left of the machine has just removed the willow sticks from the reversed fringe.

When the second revolution of the drum is completed, fringe is removed by the operator standing on the platform in back of the machine. Slats holding ends of fringe are loosened, a piece of light weight canvas laid over it and the fiber rolled into the canvas. Operation of the machine is continuous.

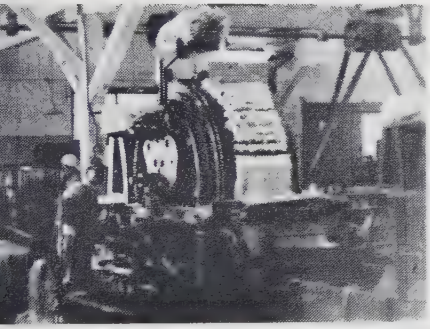
Shorter fibers are removed from the combing rolls in the form of laps and again sent through other filling engines and dressing machines to remove the shortest fibers. This results in sorting fiber into 3 lengths: long, from the first dressing frame; medium, from the second dressing frame; and short, which is fiber from filling engines and second dressing frame. Sorting fiber by lengths permits spinning of more even and stronger yarns.

Figure 13.—*Combed Fiber.* Rolls of fiber from the dressing frame are taken to the picking room, where fiber is spread over desks with lighted, ground glass tops and any remaining imperfections picked out by hand with tweezers. Girls who perform this operation work very rapidly. As inspection of each fringe is completed, fibers are pushed together into the small bundles shown in the foreground of the picture. Each of these bundles is again given a rapid inspection and placed on the wooden rack seen in the picture. At this stage the fiber is known as "filasse." The bundles of filasse are placed in large shallow boxes and taken to the yarn preparation room. Note that at this stage individual fibers have been completely separated from each other.

Figure 14.—*Forming the Lap.*—When they reach the yarn preparation room, the bundles of filasse are first weighed. If they are not of a specified weight, they are sent back to the picking room to be remade. Ten bundles of filasse are then taken to a machine called a spreader, which forms a lap as the first step in yarn preparation. At this machine, bundles of filasse are again weighed. They are then placed one by one, with ends overlapping, on a narrow endless belt, which may be seen in the right foreground of the picture. This belt carries the fiber between rollers and under a series of gill pins, i.e., a kind of comb, which makes the fibers more nearly parallel to each other. The fibers are then fed in the form of a ribbon onto a large wooden drum.

When the last or tenth bundle is placed on the belt the operator laps the ends of the first of another group of bundles over the ends of the last bundle and pinches these two ends together, causing the lap to become narrow at that point. When this narrow place appears on the drum, it is a signal to the operator that an entire lot of bundles has been made into a lap and is ready to be removed from the drum. The operator in the picture is removing a lap from the drum, an operation requiring considerable skill as the work must be done in such a manner that the arrangement of the fibers is not disturbed. The lap is carefully folded as it is removed and taken to a setting frame.

Figure 15.—*Forming the Sliver.* The lap is fed into the setting frame through a series of rolls and under gill pins which reduce its size and continue the process of arranging the fibers more nearly parallel to each other. The lap is also twisted slightly, forming what is known as a "sliver". Picture shows sliver coming from machine. Note that the machine puts a crimp in it. This helps hold the fibers together. Sliver is coiled in tall cans for transferring from one machine to another.



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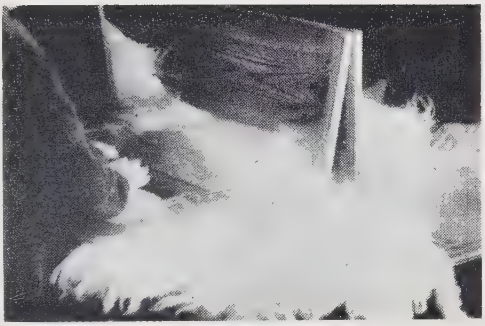

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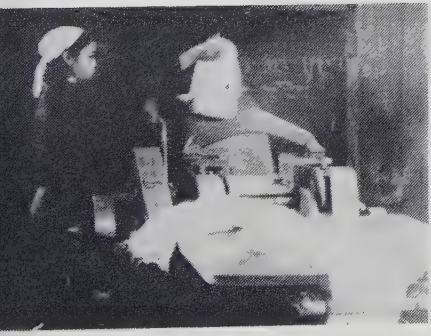


Figure 14

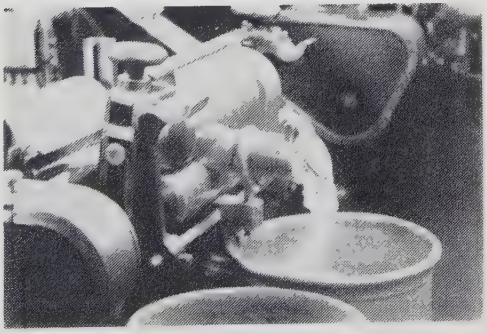


Figure 15

Figure 16.—*Drawing or Doubling.* Several slivers are fed into a drawing frame, an operation which is sometimes termed doubling. The slivers pass between rolls and under gill pins which first combine them into one sliver and then decrease the size of this sliver by drawing it out to a greater length. A small amount of additional twist is then put into it. This operation is repeated as often as necessary for the size of yarn that is to be spun in relation to the quality and size of fibers being used.

Figure 17.—*Making the Roving.* After the sliver, as a result of drawing, is of proper size and density, it is fed into a roving frame which again reduces it in size and puts additional twist in it. The result is called roving. As the roving is formed, it is automatically wound onto a wooden spool. When all of the spools on a rack are filled, they are removed from the rack and empty spools substituted.

Depending on the fineness of the yarn to be spun, roving may be fed through a second roving frame to reduce it still further in size and to increase the twist.

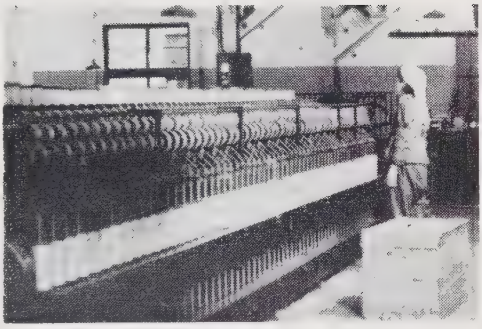
The spools of roving, when properly formed, are then taken to the spinning frame where the roving is again reduced in size and twist increased. The result is termed yarn. As it is spun, yarn is automatically wound onto small wooden bobbins.

Figure 18.—*Weaving.* After spinning, warp yarns, that is yarns which run lengthwise the fabric, must be starched to give them additional body for the weaving process. This starch is later removed from the finished fabric. After starching, warp yarns are wound onto a large cylinder which is locked into place at the back of the loom after the ends of the warp yarns have been threaded through the eyes of a series of very narrow pieces of steel, called "heddles", which are fastened into a frame called a "harness". Two or more harnesses are used in weaving. The mechanism of the loom lifts the harness in turn, thus holding the warp yarns apart and allowing the shuttle to carry the filling, that is, cross-wise yarn, back and forth to form the fabric.

The loom in the picture is making a plain weave fabric, using two harnesses. The fabric being made weighs 4 ounces per square yard. Mr. Goro Kawasumi, president of Toyo Sen-i Company, the firm owning the mills in which these pictures were taken, is observing the loom in operation.

Figure 19.—*Products Made from Ramie.* A large number of yarns, twines, and cordage fabrics, all made from ramie, are on the table. A rug made entirely from ramie is on the floor. A coil of fire hose made from ramie yarns is being carried onto the scene.

Figure 16



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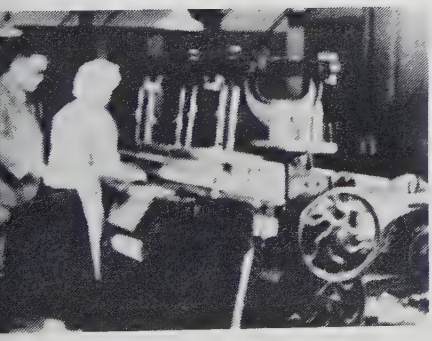

Figure 18

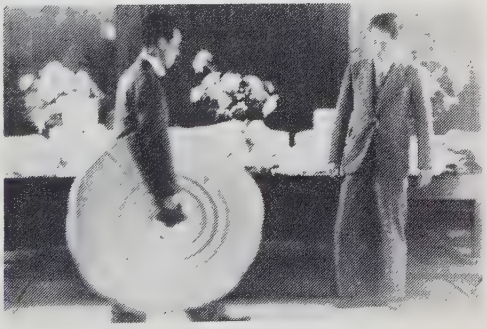

Figure 19

JUTE—FROM FIELD TO FIBER IN PAKISTAN

Elton G. Nelson *

Nearly all the jute and burlap used in the United States comes from Pakistan and India—halfway around the world. It was this distance and the threat of World War that stimulated the effort to produce a substitute in the Western Hemisphere for this versatile commodity. That substitute was kenaf. Kenaf production and processing is being mechanized but since hand-produced jute still sets the pace, it is important to know how it is grown and marketed.

Most of the jute in Pakistan and India is grown by small farmers and it is their principal cash crop. They have only a few acres and their farm implements are simple. They grow jute much as their forefathers did. The land is plowed with a crude wooden plow drawn by oxen. The seed is planted, the crop is thinned and weeds are pulled—all by hand. At harvest time the crop is cut with hand sickles. The stems are cut near the ground and tied into small bundles, either with strips of jute bark or hand-made twine. These bundles are usually left in the field for a few days, until the leaves fall off. Then they are taken to nearby pools or to slow-moving water along the edges of rivers for retting (a process of fermentation). This process takes from 10 days to 3 weeks, depending on the maturity of the stems and the temperature of the water. Removing the stems at the proper time is one of the most important factors in the production of good-quality fiber. When the jute farmer decides his jute is sufficiently retted, he wades out into the water, removes a bundle, unties it, and beats the base end of it with a small paddle-shaped club to partly loosen the fiber. Then, still standing in the water, he strips off the fiber by hand and washes adhering bark and other foreign material from the fiber by flicking it over the surface of the water. There are modifications of this procedure but the one described here is most common; all jute in Pakistan and India is stripped by hand.

Jute is dried by hanging it over bamboo frames. When it is dry, it is tied into bundles for the market. From the farmer to a middleman, on to another middleman, etc., jute is eventually accumulated at the baling centers. It comes in by oxcart or by small riverboats, either propelled by hand or by sail.

Jute is usually sorted and baled twice—first into "kutcha" bales for local transport, and second into "pucca" bales, for export. The kutcha assortment (preliminary grading) consists of top, middle, bottom, and cross-bottom and is expressed as one of these grades in connection with the town from which it originates. At this stage the fiber moves in bales weighing 250 to 320 pounds.

From the kutcha baling centers, jute usually moves to the pucca presses by rail, large riverboats and barges. As the jute comes into these large baling centers, it is given a final sorting. Since the fiber from the

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base of the stem is usually barky, 6 to 18 inches is cut off prior to grading. The fiber is then separated into several grades according to color, strength, cleanliness, appearance, etc. For each type of jute (white, tossa and Daisee) there are about 10 grades, known as public marks, but in practice, balers use their own private designation. As a result there are more than a thousand different marks or brands. The sorted fiber for export is pressed into high-density bales, about 18 by 18 by 48 inches, weighing 400 pounds each. Nearly all jute that is shipped to foreign countries goes in pucca bales, but that going to the jute mills in Calcutta is often transported in the low-compression bales, even after the pucca assortment.

The United States uses about 70,000 tons of raw jute annually; most of it is tossa, *Corchorus olitorius*. We buy the best quality fiber available.

Burlap has never been manufactured in this country, but we import about 250,000 tons annually from India. The burlap used in the United States is known in the trade as hessians and is made from a very high quality white jute. *C. capsularis*. Lower qualities go into a much heavier material called sacking—which makes up about 45 percent of the output of India's jute mills.

The methods of producing jute in Pakistan and India may seem backward. Nevertheless these methods provide us with high quality fiber. Any substitute produced mechanically will be judged by the standards established by hand-stripped jute.

The series of pictures which follow will give a good idea of some of the more important steps in jute culture and processing that have been briefly described above.

Figure 1.—"Laddering" preparatory to planting. This corresponds to harrowing as we normally do it. Plants in the background show jute ready for harvest. The land preparation is not for jute planting.

Figure 2.—Harvesting jute with hand sickles. (Photo courtesy Ludlow Mfg. & Sales Co., Boston.)

Figure 3. Placing jute in water preparatory to retting. Usually the leaves are allowed to dry and fall off before the stems are removed from the land upon which the crop was grown.

Figure 4.—First step in stripping jute following retting and beating with small paddle. Note paddle lying on stems at right.

Figure 5.—Preparing to pull fiber from upper part of stems.

Figure 6.—A more general view of the stripping operations shown in Figs. 4 and 5.

Figure 7. -Drying jute on bamboo poles. Note stripped stems in the foreground and the wall of the building in the back that was made from such stems. Near Sarisabari, Pakistan.

Figure 8.—Carrying loose jute from riverboat to sorting shed. Dacca, Pakistan.

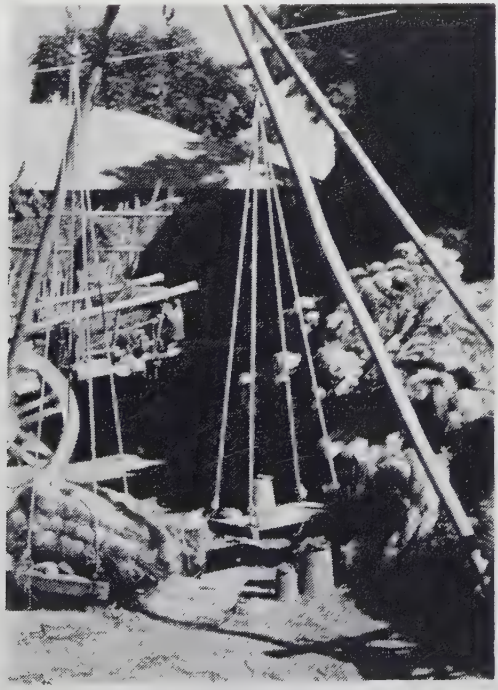

Figure 9.—Weighing loose jute.

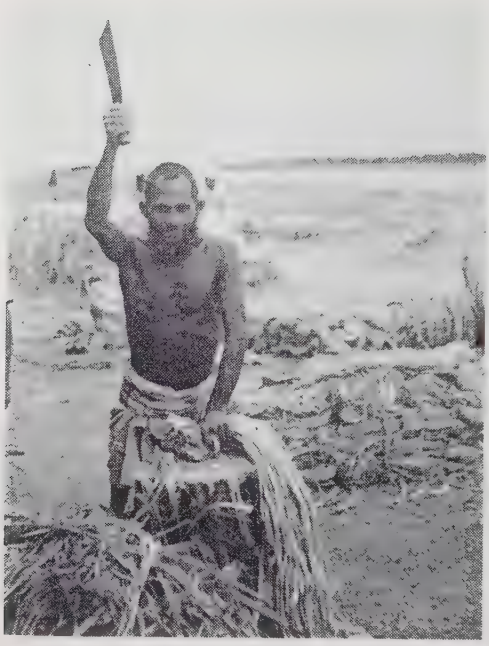

Figure 10.—Cutting jute preparatory to sorting. In this operation from 6 to 18 inches is cut from the base end of the fiber. It is to be hoped that the man was posing when the picture was taken.

Figure 11.—Softening the ends of cut jute. Narayanganj, Pakistan.

Figure 12.—Making jute ropes for tying bales. Dacca, Pakistan.

Figure 13.—Left: Kutcha bale weighing about 300 lbs. that is commonly used for domestic shipments. Right: Pucca bale for export weighing about 400 pounds that has been compressed to a density of about 40 pounds per cubic foot. The narrow dimension of the kutcha bale is about the same as that of the pucca which is approximately square. Narayanganj, Pakistan. (Ed. Note: Mr. Nelson in photo.)

Figure 14.—Pucca bale press, known as the Cyclone, is capable of exerting pressures up to 2½ tons per square inch. (Photo courtesy Ludlow Mfg. & Sales Co., Boston.)

Figure 15.—Coolie team carrying kutcha bale of jute, Narayanganj, Pakistan.

SODIUM AS A PLANT NUTRIENT

Chester D. Leonard* and Ernest C. Lundberg*

The role of sodium (Na) in the physiology of higher plants has long been, and still is, a controversial one. This paper includes a fairly comprehensive review of the literature pertaining to sodium in this role, since little information concerning this element has been published to date in Florida. Certain experiments with Na which were carried out by the writers are also reported.

LITERATURE REVIEW

It is well known that Na is essential to animal life, where it is used chiefly in the form of NaCl. Na is probably necessary to marine plant life, or at least to much of it. Osterhout (31) found it essential to several forms of algae. However, it has never been recognized as one of the essential or indispensable nutrients for the higher plants. Harmer and Benne (15) have pointed out that its presence in considerable amounts in plants has often been considered incidental, so Na has not been credited with any definite function in the metabolism of the plant. However, Lehr of Holland (23) has emphasized two points of view in considering the importance of Na to plants: the *botanic-physiological point of view*, which concerns itself with the presence or absence of deficiency symptoms in the plant when Na is withheld, and the *agricultural point of view*, which concerns itself with improving the yield and/or quality of the crop by adding Na to the growing medium.

Gilbert (12) defines an essential or "nutritive chemical element" as "one whose reduction in the diet results in decreased growth, structural abnormality, and possibly death of an organism, depending on the degree of deficiency, and whose total omission makes it impossible for the organism to exist." To date it has not been shown that higher plants cannot exist without Na. Therefore it does not meet the above requirements for an essential or "nutritive chemical element" under the botanic-physiological point of view exponded by Lehr. On the other hand, many of those crops which show no deficiency symptoms when Na is withheld have been found to produce a higher yield in both the greenhouse and under field conditions when Na has been furnished. Na has been shown, therefore, to be of considerable importance from the agricultural point of view. Wallace (41) has classified it as a "beneficial" element for certain plants.

Na is a soft, waxy, silver-white, metallic element of the alkali group. It is univalent, very active chemically, and forms a large number of important soluble salts. It occurs abundantly in the earth's crust, with 3.71% Na_2O in the outer ten miles of the lithosphere, according to the calculations of Clarke (7). On this basis, Na is the fifth most abundant mineral element in the earth's crust, ranking behind Si, Al, Fe, and Ca. It always occurs in combined form in nature, as in halite (common salt),

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Chile saltpeter, borax, glauberite, albite, diorite, and other Na-carrying minerals.

Na has been applied to soils as a fertilizer for many years as sodium nitrate, but its application was long considered merely incidental to the application of nitrogen.

Physiological Response of Plants to Na

Color of Foliage and Plant Vigor

Harmer and Benne (15) found that sugar beets fertilized with NaCl kept a vigorous, healthy green foliage longer than those without NaCl. Mangels fertilized with Na applied as $NaNO_3$ develop what Lehr (24) calls the "Na-type" of top with spreading foliage and light green color with abundant leaves, whereas calcium nitrate develops the "Ca-type" of top with compressed growth habit and dark green color, but with early withering of outer leaves.

Sayre and Vittum (34) found that table beets grown with an adequate supply of Na develop leaves that are brighter green in color and much more palatable as to flavor than those grown without it. Table beets receiving Na also developed large, strong tops which stood erect and were much better adapted to mechanical harvesting.

Tomatoes, corn, and wheat grown in sand and solution cultures develop thicker, fleshier leaves with a higher water content when an abundance of Na is furnished them (18, 6). Tomato plants grown in sand cultures with high-Na nutrient solutions display reduction in cambial activity, maturation of smaller cells, and relatively thicker walls in xylem elements and mechanical cells.

Disease Resistance

On organic soils, Na-responsive crops show less damping off in early growth, and the beet crops develop less black rot later on, when NaCl is applied along with K. Beet crops receiving NaCl show more resistance to attacks of leaf spot (*Cercospora beticola*) and celery shows more resistance to blight (*Septoria petroselini appli*). The greater gloss of leaves of these crops produced by NaCl is possibly due to an increased waxy secretion which may account for the increased disease resistance (15).

Decreased Wilting in Hot, Dry Weather

Harmer and Benne (15) report a decrease in evaporation from the soil following the application of NaCl. They found that on an organic soil, the surface of a salt-treated soil stays more moist with the result that the soil is less subject to blowing by high winds than is an unsalted soil.

Keeping Quality of Crops

Celery receiving NaCl as a fertilizer has been found to be crisper and to stay in better condition when exposed on the market (15).

Effect of Na on Absorption of Other Ions by Plants

Collander (8) found that a given plant species will exhibit a consistent type of selective absorption of several ions, but that there were wide differences in the relative selectivity among various species. All halophytes but one were distinguished by their accumulation of Na,

whereas plants like buckwheat, corn, and sunflower were noted for their pronounced exclusion of Na. Collander stresses the very complex nature of the selective salt absorption of higher plants. Van Itallie (39) found that the Na uptake depends chiefly on the uptake of K.

In general, the intake of a nutrient ion by the plant increases as the concentration of the ion increases in the growing medium. This has been shown by numerous workers.

The absence of Na in the nutrient medium of Na-responsive crops has been found to increase the absorption of K (2, 11, 15, 26). In the absence of K, however, it is evident that Na is unable to take over some of the important functions of this element, and a physiological breakdown results. In some cases the addition of Na to the nutrient medium will increase the intake of K by the plant (11, 6, 37). In a clay soil, Na intake by plants was found to be higher with a high level of calcium carbonate, probably because of Na displacement from the exchange complex by Ca of the carbonate (37).

The effect of Na on absorption of other ions varies with the nature of the accompanying anion. Breazeale (5), found that NaCl in concentrations up to 1000 ppm. in a nutrient solution did not affect the absorption of phosphoric acid by young wheat plants but decreased slightly the absorption of potash. Sodium sulfate in the same concentration depressed the absorption of potash and phosphoric acid to about 70 percent of that of the control. Sodium carbonate, on the other hand, in a concentration of 1000 ppm., reduced the absorption of potash to 20 percent of that of the control and the absorption of phosphoric acid to 30 percent of that of the control. The depressing effect of sodium carbonate was evident in concentrations as low as 100 ppm., and was marked at 300 ppm.

It has been noted in certain crops that the total milliequivalent content or "cation sum" of the four bases K, Na, Ca, and Mg tend to remain fairly constant (15, 40), but marked deviation from a constant value is encountered with some Na-responsive crops when they are provided with an abundance of the element.

Yield Responses of Various Crops to Na

Mangels

Mangels have been found to produce large increases in yield when fertilized with Na (1, 13, 22, 24, 25), even when large amounts of K are also added. This is shown by a pot experiment of Lehr, some results of which are reported in Table 1. Lehr (22) concluded that by the use of Na fertilizer, a notable saving of potash fertilizer may be made on this crop. In his experiments, the yield of roots with sodium nitrate and no K was 20 to 30 percent higher than that produced with either calcium nitrate or ammonium nitrate at any level of K. Harmer (13) obtained similar large increases of mangel yields with NaCl on organic soils in Michigan.

Sugar Beets

Sugar beets show a marked response to Na fertilization, but there is often an accompanying lowering of the apparent purity coefficient $\frac{\text{percent total sugars} \times 100}{\text{percent soluble solids by wt.}}$ of the beet juice (13, 15, 20, 28, 35). In spite of lower purity of the juice, Lill, Byall, and Hurst (28) found that

the *total recoverable sugar* increased with each addition of NaCl from 250 to 1000 lbs. per acre. Selman (35) reports that NaCl must be used with phosphate and KCl for highest yields of roots.

TABLE 1.—Yields of Mangels in Grams Dry Weight per Pot. with Three Nitrogen Fertilizers and Varying Potassium (Work of Lehr).

	No K	Normal K	Very High K
ROOTS			
$NaNO_3$	91.9	99.0	106.8
$Ca(NO_3)_2$	63.3	50.5	59.8
NH_4NO_3	54.0	63.9	54.0
TOPS			
$NaNO_3$	58.6	59.7	61.8
$Ca(NO_3)_2$	47.7	42.7	48.0
NH_4NO_3	46.5	48.6	53.7

Cotton

The yield of seed cotton has been found to be materially increased by Na fertilization, using either sodium nitrate or common salt (9, 10, 20, 29). Mathews (29) found that the average increase due to Na was 40 percent of that due to K. When 32 lbs. K_2O was applied per acre, additional Na failed to increase yields.

Table Beets

This crop produced a marked yield increase when fertilized with Na (13, 14, 15, 33, 34). Sayre and Vittum (34) also found that the use of 500 lbs. of NaCl per acre on table beets, together with a heavier-than-normal rate of planting, would produce a greater percentage of the higher-priced small beets without reducing total yield of roots. Some yields of table beets with and without Na are shown in Table 2.

TABLE 2.—6-Year Average Yields of Table Beets Grown on Muck Soil in Michigan with Varying Amounts of Na and K in the Fertilizer (Work of Harmer).

Fertilizer Application Each Year 600 Lbs./Acre	Yearly NaCl Lbs. Applied	Yield of Roots Tons/Acre
0-8-24	0	10.4
0-8-24	500	19.3
0-8-24	1000	21.9
0-8-12	500	18.2
0-8-48	0	17.0
0-8-0	500	5.6

Turnips

Substantial increases in yield of turnips have been obtained (13, 14) by adding either 500 or 1000 lbs. of NaCl per acre to organic soil in

the field (Table 3). Large growth increases have also been obtained in sand culture (20).

Celery

Harmer (13, 14) has obtained substantial increases in celery yield by adding either 500 or 1000 lbs. of NaCl per acre to organic soil in the field, but such increases were obtained only when K was furnished (Table 3).

TABLE 3.—Yields of Celery, Swiss Chard, and Turnips Grown on Muck Soil with Varying Amounts of Na and K in the Fertilizer (Work of Harmer).

Yearly Fertilizer 600 Lbs./Acre	Yearly NaCl, Lbs.	Yields, Tons/Acre		
		Celery	Swiss Chard	Turnips
0-8-24	0	19.2	17.7	9.8
0-8-24	500	25.3	26.5	13.6
0-8-24	1000	25.5	31.0	15.5
0-8-12	500	22.3	23.5	11.6
0-8-48	0	22.9	23 0	12.4
0-8-0	500	11.9	7.7	4 2

Swiss Chard

NaCl applied at the rate of either 500 or 1000 lbs. per acre to organic soils in the field has produced large yield increases of Swiss Chard (13, 14, 15), as shown in Table 3. It will be noted that an 0-8-24 fertilizer with no NaCl produced 17.7 tons of Swiss Chard per acre. The same fertilizer plus 1000 lbs. NaCl produced 31.0 tons per acre.

Oats

Holt and Volk (20) obtained marked yield increases of oats in sand cultures by adding Na, even after adding 144 lbs. K_2O per acre.

Wheat

Sand and solution culture studies have shown that wheat will respond well to Na fertilization (4, 6, 20). Butkevich and Maruashvili (6) report that the yield of wheat was increased by Na up to Na/K ratios of about 5, then decreased. They found that Na can be substituted for 25 to 75 percent of the K without detriment to plant yield.

Barley

Lehr (24) states that barley responds well to Na, very much like the response of oats. Richards (32) reports that Mullison and Mullison obtained considerable increase in dry weight of barley from Na.

Flax

Some yield increases in flax from Na fertilization have been reported by Hartwell and Damon (17).

Radish

Na salts increased growth of radish as with limited K, but the benefit ceased when ample K was supplied (1).

Other Crops

Various workers have reported little or no increase in yield from Na fertilization of onions, cabbage, parsnips, carrots, potatoes, corn, vetch, tomatoes, rice, giant summer squash, soybeans, rutabagas, cucumbers, and chicory. Differing experimental conditions may, however, produce different results. Leonard and Bear (26) found in a field experiment that 265 lbs. Na_2O per acre, applied to the soil in the form of common salt both with and without 100 lbs. K_2O, increased yields of tomatoes to a point closely approaching the level of statistical significance.

General Classification of Crops with Respect to Their Na Responses

Harmer and Benne (15), after extensive review of the literature, have classified those crops on which Na has been tried as a fertilizer into *tentative* groups as shown in Table 4.

TABLE 4.—Tentative Classification of Various Crops with Respect to Their Response to Na Fertilization (by Harmer and Benne).

A. Crops benefited by Na with deficiency of K.

Group 1. *None to very slight benefit.* Buckwheat, corn, lettuce, onion, parsley, parsnip, peppermint, potato, rye, soybean, spinach, strawberry, squash, sunflower, and white bean.

Group 2. *Slight to medium benefit.* Asparagus, barley, broccoli, Brussels sprout, flax, caraway, carrot, chicory, cotton, millet, oats, peas, rutabaga, tomato, vetch, and wheat.

B. Crops benefited by Na with sufficiency of K.

Group 3. *Slight to medium benefit.* Cabbage, celeriac, horseradish, kale, kohlrabi, mustard, radish, rape.

Group 4. *Large benefit.* Celery, mangel, sugar beet, Swiss chard, table beet, turnip.

Some Theories Advanced to Explain the Beneficial Effects of Na on Plants

Many different theories or explanations for the benefits to plants due to sodium fertilization have been advanced. Some of these are listed below.

Na can participate in maintenance of ionic balance in the cell sap. Arnon (2) suggests this theory. Lehr (23) also emphasizes the importance of ionic equilibrium in the plant.

Na serves as a replacement for K in the plant, or a substitute for it. Various workers support this view (10, 15, 20, 25, 30). Lehr (25) found that good production of mangels is impossible without Na. Holt and Volk (20) conclude from their work that Na functioned as an essential plant nutrient for some crops, notably oats, wheat, and sugar beets.

Na may have a function independent of K in the plant. Lehr (25) takes this view with respect to mangels. He believes that Na does not serve as a replacement for K with this crop, but is essential for its proper growth.

Na serves to bring about equilibrium of cations in the plant. Lehr (25) states that in the equilibrium of cations, the decisive factor is the exact proportion rather than absolute quantity. He found that both K and Na exerted a strong influence on the activity of Ca. Garman (10) feels that Na may function actively in over-all ionic balance and buffer-capacity relationships within the protoplasm. Related views are expressed by Van Itallie (38, 39) and by Bower and Pierre (3).

Na decreases evaporation from the soil surface. This effect was noted by Harmer and Benne (15) from NaCl applications.

Na may free K or other plant nutrients in the soil by exchange and thus increase the amount of available nutrients. Lehr (23) discounts this theory. It is evident that if K can be exchanged by Na in the soil, it is already available to the plant. On the other hand, if the K is fixed in the crystal lattice of minerals, it cannot be released by Na, since Na cannot occupy the place of K in this position.

Na increases the osmotic concentration of the cell sap. Garman (10) has suggested this theory. Other workers (11, 16, 18) state that this effect cannot account for the benefits of Na.

Na antagonizes the toxic effect of other elements or salts in solution. Osterhout (31) found this action important in algae. Richards (32) expresses his view of the most likely relationship of Na to K as follows:

"Sodium cannot perform the primary essential function of K. When the K level is too low to exert this function adequately, toxic accumulations of other elements may occur, producing characteristic symptoms and reducing growth still further, or even leading to death of the plant. Na may hinder or entirely suppress such accumulations, thus improving the general condition: it may also increase phosphorus uptake with either favorable or detrimental results. In some plants, such as barley, however, Na may itself accumulate to toxic levels, resulting in secondary injury of a modified type; but in others (beet, mangel) higher internal concentrations are tolerated and considerable improvement results. In these plants Na may exert a beneficial effect even when the K supply is sufficiently high not to limit growth directly; but in barley at high K levels large increases in yield due to Na are not found, although the plant type is again modified in its presence. The toxic effects postulated may indeed be due to unbalanced values of the internal cation ratios, but probably are due largely to direct accumulations."

Na increases availability of phosphorus. Only indirect evidence has been advanced to support this view.

EXPERIMENTAL[1]

Greenhouse Experiment with Red Table Beets

A greenhouse experiment was conducted to determine the value of Na to red table beets. The test was made in 1½-gallon glazed earthenware pots filled with well-washed, quartz sand. Plants were grown from seed and thinned to five per pot. Nine nutrient solutions were used, with three levels of K and three of Na at each K level. Except for variations in K, each solution contained a balanced supply of all known essential

[1] Part of the work reported in this section was carried out in New Jersey and was published in New Jersey Agricultural Expt. Sta. Bul. 752, October 1950.

TABLE 5.—Dry Weight of Table Beets Grown in Sand Culture with Varying Levels of Na and K.

Treatment — ppm.		Yield in Grams	
Na	K	Tops	Roots
0	195	24.94	38.90
23	195	25.15	37.95
115	195	24.55	32.41
0	20	13.20	10.08
23	20	17.17	19.90
115	20	28.13	31.05
0	4	3.56	0.35
23	4	13.83	6.13
115	4	25.30	3.31

plant nutrients. About two quarts of solution was applied to each pot daily by the continuous-drip method. After 2½ months of growth, the plants were harvested. Yields are shown in Table. 5. The best growth was obtained with the high-K level (195 ppm.). Addition of Na at that level produced no increase in yield. The medium-K level (20 ppm.) was not sufficient for best growth, but addition of Na at this K level resulted in marked increases in yield of both roots and tops. Addition of a medium amount of Na to the medium-K culture nearly doubled the yield of roots, and application of more Na gave an even larger increase in yield.

TABLE 6.—Na and K Content of Table Beets Grown in Sand Culture.

Treatment — ppm.		m.e per 100 gms.*			
		Tops		Roots	
Na	K	Na	K	Na	K
0	195	0	291	1	103
23	195	74	215	7	94
115	195	143	173	20	90
0	20	10	68	2	69
23	20	120	32	37	61
115	20	321	18	84	46
0	4	3	42	7	78
23	4	136	19	57	25
115	4	302	19	100	13

* Milliequivalents in 100 grams of oven-dry tissue. These are expressed as milliequivalents because K and Na do not replace each other gram for gram but in proportion to their combining weights. Thus 39 parts K are equivalent to 23 parts Na. To convert milliequivalents K and Na to percentages, multiply by 0.0391 and 0.023, respectively.

The beets in the low-K and no-Na culture were very small. Addition of Na produced marked increases in yield of both tops and roots at this level of K, but growth was still not satisfactory. Obviously, more K

than was supplied in this treatment was needed for normal growth. This indicates that Na performs only part of the functions of K in the nutrition of beets.

The Na content of both tops and roots increased consistently with each increase in Na at all three levels of K in the nutrient solution, as shown in Table 6. At any given level of Na, its content in the beets increased as the K content of the nutrient solution was reduced. Likewise, the K content of the beets decreased with increase of Na in the nutrient solution. This indicates a replacement of K by Na.

Greenhouse Experiment with Celery

In another greenhouse experiment, celery was grown in sand culture with three levels of K (195, 39, and 8 ppm.). In the pots receiving the two lower levels of K, the difference between that level and 195 ppm. K was replaced by an equivalent amount of Na. The three treatments were as follows: Zero Na and 195 ppm. K; 92 ppm. Na and 39 ppm. K; and 110 ppm. Na and 8 ppm. K. The celery yield increased as the K was reduced from 195 to 39 ppm. and replaced by an equivalent amount of Na. These increased yields were maintained when the K was further reduced to 8 ppm. and replaced by an equivalent amount of Na. Similarly, the Na content of the celery rose rapidly and the K content decreased. Results are shown in Table 7.

TABLE 7.—Dry Weight of Tops and Na and K Content of Celery Leaves Grown in Sand Culture at Varying Na and K Levels.

Treatment		Yield of Tops	Composition	
Na ppm.	K ppm.	gms.	Na m.e.*	K m.e.*
0	195	59.2	0	135
92	39	67.2	87	42
110	8	69.1	143	17

* Milliequivalents per 100 grams dry tissue.

Outdoor Pot Experiment with Spinach

An outdoor pot experiment with 18 different treatments of Na and K, each in triplicate, was carried out with spinach, using Sassafras loam soil from a location which had not been farmed for many years. The top 7 inches was topsoil, and the rest subsoil. The topsoil was brought to pH 6.5 by applying a mixture of calcium carbonate and magnesium carbonate at the rate of 6000 lbs. per acre. Each pot received an application of ammonium nitrate equivalent to 100 lbs. N per acre, and monocalcium phosphate equivalent to 100 lbs. P_2O_5 per acre. Boric acid equivalent to 20 lbs. of borax per acre was also applied.

K was applied as KCl at six different rates—0, 25, 50, 100, 150, and 200 lbs. K_2O per acre. At each of these K levels, Na was applied as NaCl at three different levels—equivalent to 0, 100, and 200 lbs. K_2O per acre. The spinach was thinned to five plants per pot.

Yields

At the 0, 25, and 50-lb. levels of K_2O, significant to highly significant yield increases were obtained from both the 100- and the 200-lb. levels of Na. At the 100-lb. level of K_2O, only the 200-lb level of Na produced a significant yield increase. At the 150- and 200-lb. K_2O levels Na failed to produce a significant increase in yield.

Comparison of the mean yields of each group of 18 pots receiving the same level of Na (disregarding the different K treatments) shows:

(a) The 100-lb. Na level gave a highly significant increase (1% point) over zero Na.

(b) The 200-lb. Na level gave a highly significant increase over zero Na, and a significant increase (5% point) over 100 lbs. Na.

The above results indicate that Na is of considerable value as a fertilizer for spinach at low to moderate levels of K fertilization.

Outdoor Cylinder Experiment with Spinach

An experiment with spinach, using different sources of nitrogen, was carried out to determine whether the Na in nitrate of soda had any value to this crop. Five treatments were used, in triplicate, including Chilean nitrate of soda, chemically pure sodium nitrate, calcium nitrate, and ammonium nitrate, plus a check with no nitrogen. Each of the four fertilizers was applied at the rate of 100 lbs. N per acre. The cylinders were 36 inches deep and 22 inches in diameter. About 20 inches of subsoil was first placed in each cylinder, and this was covered by 10 inches of topsoil of Sassafras loam. The soil was taken from an area that had not been cropped for many years. It was in good physical condition but was low in available plant nutrients. The cation exchange capacity was 8.0 m.e. per 100 grams of soil, and the exchange level of the various bases in it was as follows: Ca, 0.29 m.e.; Mg, 0.22 m.e.; K, 0.44 m.e. per 100 grams. The soil had an original pH of 4.5. This was raised to pH 6.5 by applying the equivalent of 6000 lbs. of dolomitic limestone per acre in the form of a mixture of chemically pure calcium carbonate and magnesium carbonate. The lime was mixed with the upper 6⅔ inches of soil in each cylinder. Each cylinder also received a basic treatment of 100 lbs. of P_2O_5 per acre applied as mono-calcium phosphate, and also the equivalent of 20 lbs. of borax per acre, applied as boric acid. No K was added to any of the cylinders.

Early Growth of Crops

Within a week after the spinach plants emerged, it was very evident that both of the sodium nitrate fertilizers were far superior to calcium nitrate and ammonium nitrate in promoting growth of this crop at early stages. The soil used in the test was low in available K, and the Na added in the sodium nitrate evidently performed some of the functions of K in these crops.

There was little difference between the growth produced by commercial sodium nitrate and that with C. P. sodium nitrate, although a distinctly heavier stand of spinach was obtained with the commercial source. Both of these sodium-carrying fertilizers gave spinach a distinct boost in growth which started immediately after emergence from the ground. Not only did they produce a better stand on emergence, but they also

produced stronger plants which had a much higher percentage of survival. Many of the plants which came up in the check cylinders and in those receiving either calcium nitrate or ammonium nitrate died within two weeks.

Yields

The yields of the spinach crop are shown in Table 8. It is evident from these data that sodium nitrate was far superior to either calcium or ammonium nitrate under the conditions of this experiment. Since the amount of N applied was the same with each fertilizer, the large increases in yield obtained with the two sodium nitrate fertilizers must be attributed to the effect of the Na. This Na has evidently served to supplement the K needs of the plants where insufficient K was available to them from the soil.

TABLE 8.—Yield of Spinach Grown in Sassafras Loam Soil in Outdoor Cylinders with Different Nitrogen Fertilizers.

Treatment	Yield — Gm.*	% of Check
$NaNO_3$—Chilean	23.5	5211
$NaNO_3$—C. P.	21.9	4860
NH_4NO_3—C. P.	1.8	402
$Ca(NO_3)_2$—C. P.	1.0	226
Check (No N)	0.4	100

* Dry wt., mean of 3 replications.
L.S.D.: 3.97 gm. at 5% point;
5.87 gm. at 1% point.

Analysis of variance showed that the yields obtained with the two sodium nitrate fertilizers were highly significant (1% point) over all other treatments. The difference between the yields from commercial and C. P. sodium nitrates was not significant.

Plant Composition

The composition of the spinach plants (tops) is shown in Table 9.

TABLE 9.—Composition of Tops of Spinach Crop Grown in Sassafras Loam Soil in Outdoor Cylinders with Different Nitrogen Fertilizers.

Treatment	Na m.e.*	K m.e.*	Ca m.e.*	P Percent
Sodium nitrate (Chil.)	112	23	45	0.50
Sodium nitrate (C. P.)	112	22	42	0.56
Ammonium nitrate	1	27	64	0.45
Calcium nitrate	2	19	70	0.40
Check (no N)	0	21	66	0.38

* m.e. per 100 gms. oven-dry tissue.

It is evident from the analysis of the spinach plants that the Sassafras loam soil used in this experiment contains very little available Na, since

the Na content of the plants was very low except where sodium nitrate was used. The addition of sodium nitrate greatly increased the content of Na in both tops and roots. There was little fluctuation in K content of the tops, but the plants receiving sodium nitrate had considerably less K in the roots than those receiving the other treatments. The calcium content of the tops was considerably reduced in the plants receiving sodium nitrate. The phosphorus content was greater in the tops of those plants receiving sodium nitrate.

Outdoor Cylinder Experiment with Celery

An outdoor cylinder experiment with celery somewhat similar to that reported above for spinach was also carried out. In this experiment, only one sodium nitrate fertilizer, the Chilean nitrate of soda, was used, and the C. P. sodium nitrate was replaced with potassium nitrate. Each of the four N fertilizers was applied at the rate of 100 lbs. N per acre, and a second application was made three months later because of a delay in obtaining celery plants. It was believed that much of the Na and N from the first application had been lost by leaching.

Before the first application of nitrogen fertilizer, each cylinder received a treatment of 50 lbs. K_2O per acre as KCl, 100 lbs. P_2O_5 as mono-calcium phosphate, and the equivalent of 20 lbs. borax per acre as boric acid.

Yields

The yields of celery tops are shown in Table 10.

TABLE 10.—Yield of Celery Tops Grown in Sassafras Loam Soil in Outdoor Cylinders with Different Nitrogen Fertilizers.

Treatment 100 Lbs. N	Green Weight gm.	Dry Weight gm.
Check—No N	521	73.0
$NaNO_3$—Chilean	1415	161.0
KNO_3	1472	169.3
$Ca(NO_3)_2.4H_2O$	405	57.3
NH_4NO_3	335	46.6

It will be noted that the differences in yield between sodium nitrate and calcium and ammonium nitrates are not so large as they were with spinach. This is not because celery responds less to sodium as a fertilizer, but rather because of the 50 lbs. of K_2O added to all cylinders. No K was added to the spinach. These data show that sodium nitrate was as effective as potassium nitrate, and far more effective than calcium nitrate or ammonium nitrate, in increasing celery growth. It is evident that Na has quite successfully supplemented K in the celery plant. This is in agreement with results obtained with celery in sand culture work.

Composition

The composition of celery tops is given in Table 11.

These data show that the plants receiving commercial sodium nitrate contained much less K than those receiving potassium nitrate, and also

TABLE 11.—Composition of Tops of Celery Plants Grown in Sassafras Loam Soil in Outdoor Cylinders with Different Nitrogen Fertilizers.

Treatment	Na m.e.*	K m.e.*	Ca m.e.*
Check—No N	11	24	127
Sodium nitrate (Chilean)	173	18	82
Potassium nitrate	46	90	85
Calcium nitrate	16	28	155
Ammonium nitrate	20	33	135

* m.e. per 100 grams oven-dry tissue.

less than the plants receiving the other treatments. Because of the much higher yield of the sodium nitrate plants, however, they took up more total K than the calcium nitrate, ammonium nitrate, or check plants.

Some comparisons of total intake of K by the celery plants receiving different treatments are recorded in Table 12.

TABLE 12.—Absorption of K by Celery Plants Grown in Sassafras Loam Soil with Different Nitrogen Fertilizers.

Treatment	K/gm. m.e.	Yield Dry Wt. gms.	Total K (2)x(3)
Check	.239	73.0	17.4
$NaNO_3$	.179	161.0	28.8
KNO_3	.900	169.3	152 4
$Ca(NO_3)_2$	.281	57.3	16.1
NH_4NO_3	.332	46.6	15.5

These data show that the celery plants receiving potassium nitrate took up more than five times as much total K in the tops as did those receiving sodium nitrate. Specifically, 152.4 - 28.8, or 123.6 m.e. more K was absorbed by the potassium nitrate plants than by the sodium nitrate plants. To balance this large difference in K uptake, the sodium nitrate plants absorbed a total of 278 m.e. Na. The potassium nitrate plants, on the other hand, absorbed a total of only 78.0 m.e. Na. The difference between these two amounts is 200 m.e. of Na, which for all practical purposes (as far as yield is concerned) completely performed the functions of the extra 123.6 m.e. of K taken up by the potassium nitrate plants. Since K outweighs Na 39.1 to 23, 123.6 m.e. of K weighs 4.8 grams, whereas 200 m.e. of Na weighs only 4.6 grams. Thus the extra K absorbed by the KNO_3 plants was satisfactorily replaced by a slightly smaller weight of extra Na absorbed by the plants receiving $NaNO_3$.

Studies with Radioactive Na (Na^{22})

Several studies were made with radioactive Na (Na^{22}). This is an isotope of ordinary Na and is produced in the cyclotron from magnesium. It is unstable and displays radioactivity as it disintegrates, with emission of beta and gamma radiations, to form neon, an inert gas. It has a half-life of three years.

When Na^{22} is fed to plants in solution it is absorbed by them like ordinary Na. Its presence in very small concentrations in any plant part can be detected by using a Geiger counter. Since the radiations emitted by Na^{22} will darken a photographic film, a radioautograph showing distribution of the Na^{22} in a leaf or other plant part containing the isotope can be made by exposing the film to the plant part in the dark.

In one test, a tomato plant was grown to maturity in sand culture, using a complete nutrient solution without Na. One microcurie[2] of Na^{22} was supplied to the plant 7 days before harvest. Table 13 shows the concentration of the isotope in the various plant parts.

TABLE 13.—Accumulation of Na^{22} in Mature Tomato Plant After Treatment in Sand Culture with 1 Microcurie of the Isotope.

Plant Part	CPM *
Petioles, large new leaves	15,600
Growing point	10,000
Large new leaves	5,800
Petioles, old leaves	2,800
Old, mature stems	3,100
Old leaves	800
Green fruit, ¾ inch diameter	7,700
Green fruit, 2½ inches diameter	3,300
Large newly ripened fruit	3,100
Dead-ripe fruit	2,000

* Counts per minute per gram dry tissue, as measured in plant ash by Geiger counter.

It is obvious from these data that the younger parts of the plant contained the larger amounts of Na^{22}. With increasing maturity, the leaves, stems, and fruit contained less Na^{22}. The conducting tissues contained the highest concentration of the isotope, as shown in the petioles of large new leaves.

TABLE 14.—Rates of Absorption of Na^{22} by Tomato Plants Grown in Pot Culture and Treated with 2.5 Microcuries of the Isotope.

Hours	195 K Leaf	No Na Petiole	8 K Leaf	110 Na Petiole
¼	0	0	0	0
½	0	34	0	72
1	0	89	56	448
3	0	176	630	879
18	96	363	2676	.....
42	273	.....	4473	6465
66	591	663	7506	11124
90	765	747	3354	4221
94	339	282	3933	18357

[2] One microcurie is the amount of the radioisotope required to emit 2,200,000 radiations per minute, or 37,000 radiations per second.

In another experiment with radioactive Na, tomato plants were grown in sand cultures at three levels of K and Na until they were 4 feet high and were bearing small green fruit. Radioactive Na^{22} was applied at the rate of 2.5 microcuries to the surface of the sand in the pots and watered in with the same type of nutrient solution that had been supplied previously to the plants. The first mature compound leaf below the growing tip, normally about 6 inches away, was collected and separated into leaflets and petioles. Movement of Na^{22} into the leaves and petioles sampled is shown in Table 14 for the highest and lowest levels of K.

The figures given in the table represent counts per minute per gram of dry tissue, as measured in the plant ash with a Geiger counter.

No movement of Na^{22} into the petioles of the first mature leaf was noted until one-half hour after it was applied to the sand. Translocation of Na^{22} from the petioles into the blades of the leaflets in detectable amounts did not occur with the high-K and no-Na treatment until sometime between the 3- and 18-hour sampling periods. With the low-K and high-Na treatment, however, the presence of Na^{22} in the leaflets was noted after 1 hour. The intake of Na^{22} was considerably greater in the low-K treatment.

In work reported elsewhere, Leonard and Toth (27) found appreciable concentrations of Na^{22} in celery leaves and stems only 15 minutes after application of the isotope to the nutrient medium. Na^{22} was found to be concentrated in the plant sap of tomatoes, radishes, oats, and lettuce where from 57 to 91 percent of the absorbed Na^{22} was found.

Stewart and Bear (36) made radioautographs of Ladino clover plants fed Na^{22}. One plant received abundant K and contained about 6% K in the tissue; in this plant the Na^{22} was concentrated in the stems and old leaves, with considerably less in the young leaves and growing point. The other plant received inadequate K, and contained only about 1% K in the tissue; in this plant, the Na^{22} was concentrated in the growing point and young leaves, with considerably less in the older leaves.

Uptake of Na by Citrus

Experimental work with Na uptake of citrus trees and its effects on their growth is now in progress. A few preliminary results of this work are presented herewith.

Greenhouse Experiment

A preliminary 3 x 3 factorial experiment, without replication, was run in the greenhouse to study the uptake of both Na and K when these elements were supplied in varying amounts in the nutrient solution. Rough lemon trees, grown from cuttings, were planted in well-washed quartz sand in clay pots painted inside with bituminous paint. The sand in the pots receiving no K was washed with strong HCl and then washed with deionized water until no chlorides remained. The plants were fed with a nutrient solution which was complete except that it contained no K.

There was no noticeable difference due to treatment in growth of the plants during the 6 months this experiment was in progress, except for a few leaf symptoms. However, the chemical analyses of the leaves and roots, as presented in Table 15, show considerable differences in uptake of Na and K under the different treatments.

TABLE 15.—Na and K Content of Rough Lemon Cuttings Grown in Sand Cultures at Varying Na and K Levels.*

Treatment Levels		Leaves		Roots	
Na ppm.	K ppm.	Na Percent	K Percent	Na Percent	K Percent
0	0	0.098	0.24	0.029	0.37
46	0	0.383	0.19	0.312	0.26
230	0	0.746	0 29	0.604	0.36
0	4	0.242	0.60	0.212	0.33
46	4	0.212	0.33	0.483	0.42
230	4	0.483	0.50	0.260	0.69
0	78	0.075	1.15	0.123	1.25
46	78	0.080	1.63	0.053	1.15
230	78	0.475	1.90	0.108	0.96

* The nutrient solutions were made up as follows: 0.0045 M $Ca(NO_3)_2$; 0 0040 M $MgSO_4$ 7 H_2O; 0.00075 M $NH_4H_2PO_4$; 0.04 ppm. Zn; 0.50 ppm. Fe; 0.29 ppm. Mn; 0.04 ppm. Cu; and 0.26 ppm. B.

Na and K were added, in the amounts indicated, as the sulfates.

At the zero K level, it will be noted from Table 15 that the Na content of both leaves and roots increased regularly as the concentration of Na in the nutrient solution increased. The K content varied erractically, dropping at the 46 ppm. level of Na in both leaves and roots, with little difference between the zero Na and the 230 ppm. Na levels.

At the 4 ppm. K level, the behavior of Na in the leaves and roots was more irregular than at the zero K level. In the leaves, the Na content was slightly lower at the 46 ppm. Na level than at the zero Na level, but increased considerably at the 230 ppm. Na level. In the roots the Na content was highest at the 46 ppm. Na level, and decreased at the 230 ppm. Na level. The K content of the leaves decreased somewhat irregularly as the Na level rose in the nutrient solution, but the K content of the roots increased with increasing Na level of the nutrient solution.

At the 78 ppm. K level, which is considered an adequate supply of K for citrus, the Na content of the leaves increased only slightly with 46 ppm. Na in the nutrient solution, but increased greatly at the 230 ppm. Na level. At the same time, the Na content of the roots decreased irregularly as the Na level rose in the nutrient solution. The K content of the leaves increased with increasing levels of Na, but decreased in the roots. Thus, at an adequate K level, Na and K behaved almost alike with increasing concentration of Na in the nutrient solution.

At the 230 ppm. Na level, the Na content of the leaves was greatest with zero K, and nearly equal for the 4 and 78 ppm. K levels. The Na content of the roots decreased as the K increased in the nutrient solution so that the Na content is much lower at 230 ppm. Na with the 78 ppm. K level as compared to the zero K level.

Field Experiment with Citrus

A small field experiment consisting of 28 single-tree plots of full grown trees has been set up to study the uptake of Na by citrus. Several

varieties of oranges and grapefruit, and one variety of Satsuma, on both sour orange and rough lemon rootstocks, are represented. On March 15, 1951, varying amounts of K were applied (0, 12, and 20 lbs. of 8% K_2O fertilizer per tree) and varying amounts of Na (0, 4½, 9, 18, and 45 lbs. of NaCl per tree) were applied at the same time. On March 20, 12 lbs. of an 8-0-0-6-2-1 fertilizer mix was applied to each grapefruit tree and 10 lbs. of the same mix was applied to each orange and Satsuma tree. All materials containing Na or K were omitted from the mix.

The various plant parts were sampled on June 26, 1951 and analyzed to determine which part would serve as the best index of Na uptake by the plant. There was no significant increase in Na content in the various parts of the trees where 4½, 9, or 18 lbs. of NaCl was applied but there was a considerable increase where 45 lbs. of NaCl was applied (Table 16). It appears that the leaves will give the best indication of Na uptake and also will be much easier to handle.

TABLE 16.—Na and K Content of Various Parts of Inman Grapefruit Trees Budded on Rough Lemon Rootstock with and without Added NaCl. All K Was Omitted from the Spring Fertilizer Application.

Plant Part	45 Lbs. NaCl (No K)		No NaCl (No K)	
	K Percent*	Na Percent*	K Percent*	Na Percent*
Spring flush leaves	2.08	0.555	2.88	0.053
Old leaves (1950 flushes)	1.46	0.312	1.54	0.091
Spring flush twigs	1.71	0.024	1.65	0.020
Older twigs, up to $\frac{3}{16}$ inch	0.96	0.024	0.83	0.024
Bark, old twigs, $\frac{3}{16}$-$\frac{3}{8}$ inch	1.25	0.030	1.29	0.032
Wood, older twigs, $\frac{3}{16}$-$\frac{3}{8}$ inch	0.46	0.020	0.42	0.010
Bark of twigs $\frac{3}{8}$-$\frac{5}{8}$ inch	1.02	0.027	1.13	0.027
Wood of twigs $\frac{3}{8}$-$\frac{5}{8}$ inch	0.42	0.013	0.42	0.005
Roots, approximately $\frac{3}{8}$ inch	0.73	0.216	0.46	0.010
Roots, approximately $\frac{3}{16}$ inch	0.83	0.320	0.69	0.036
Roots, ¼ inch or less, with rootlets	1.04	0.262	1.25	0.093

* Percent of the dry matter.

There was no significant difference in the analyses of samples washed in Vel and thoroughly rinsed, and those not washed.

The data in Table 16 show that the leaves and roots were definitely higher in Na in the tree receiving the 45 lb. application of NaCl but the other plant parts were not greatly affected. The K content of the spring flush leaves from the tree receiving 45 lbs. of NaCl is slightly lower than that of the tree receiving no NaCl.

On July 30, 1951, 100 lbs. of NaCl was applied to the soil beneath a Marsh seedless grapefruit tree. On August 10, definite toxicity symptoms were observed and samples were taken of various plant parts (Table 17). The toxicity symptoms observed first were a yellowing at the tips and edges of the leaves, followed by burned tips and leaf edges. There were also some burned spots in the central part of the leaves. A heavy leaf fall occurred after the appearance of these symptoms. These toxicity symptoms are very similar to the symptoms shown by a tree in sand culture to which was added no K and 230 ppm. Na from Na_2SO_4.

TABLE 17.—Na and K Content of Various Parts of a Marsh Seedless Grapefruit Tree Treated with 100 Pounds of NaCl Added to the Soil Surface.

Plant Part	Na Percent	K Percent
Spring flush leaves	1.150	1.50
Old leaves (1950 flushes)	0.912	2.34
Roots (up to ¼ inch)	0.292	0.54
Green twigs	0.438	0.67
Older twigs, up to $\frac{7}{16}$ inch	0.212	0.29

The data in Table 17 show that the Na content of all plant parts analyzed increased considerably over that found in the tree treated with 45 lbs. NaCl. The Na content of the spring flush leaves was about doubled, and that of the older leaves nearly tripled. The Na content of the larger twigs was increased about 16 times, and that of the green twigs slightly more than that. The roots showed a much smaller percentage increase. The K content decreased in the young leaves and increased in the older leaves, over that found with the 45-lb. treatment with NaCl.

SUMMARY

Although Na is not recognized as an essential element for the growth of higher plants, many crops will produce higher yields with Na as a fertilizer than without it. A review of the literature is presented covering physiological responses of various plants and yield responses of various crops to Na, and many of the theories advanced to explain the beneficial effects of Na on certain plants.

Na and K behave somewhat alike in their effect on plant growth. The amounts of K available to a plant usually affects its response to added Na.

Table beets grown in sand cultures showed large increases in yield from added Na with either 4 or 20 ppm. K in the nutrient solution, but gave no yield increase to this element with 195 ppm. K available.

Yields of celery in sand cultures increased as the K was reduced from 195 to 39 ppm. and replaced by chemically equivalent amounts of Na in the nutrient solution.

Nitrate of soda gave much higher yields of spinach than did either ammonium or calcium nitrate when each was supplied in an amount equivalent to 100 lbs. N per acre to Sassafras loam soil without added K. The increased yields are attributed to the Na carried in nitrate of soda.

Celery fertilized with nitrate of soda yielded far more than that receiving either ammonium or calcium nitrate and nearly equalled the yield of that receiving potassium nitrate.

Spinach yields in outdoor pots filled with Sassafras loam soil were significantly increased by the use of Na equivalent to either 100 or 200 lbs. K_2O per acre, when receiving no K or when fertilized with 25 or 50 lbs. K_2O per acre. Na accumulation in the conducting tissues of plants was confirmed by activity measurements and radioautographs with radioactive Na^{22}. Na^{22} was found in leaf petioles of tomato plants within 30 minutes after it was applied to the growing medium.

In preliminary studies, citrus trees were found to take up low amounts of Na except when it was furnished in high concentrations.

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SODIUM AND POTASSIUM INTER-RELATIONSHIPS IN PANGOLA GRASS

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The substitution of sodium for at least part of the potassium required for plant growth has been recognized for many years. Unfortunately we know little more about this relationship than did J. A. Turner when he wrote in the Cotton Planter's Manual of 1856 (5). "As to soda, it stands nearest in its chemical character to potash, and though it is itself not nourishment for plants, to any great extent, as the quantity of it decreases in plants in proportion to their cultivation, it nevertheless acts as a substitute for potash, in the same manner as magnesia for lime. The composition of the cotton staple, as given above shows the presence of soda in its ash in no small quantity. This circumstance seems to express, in accordance with the analysis of the soil, that by the scarcity of potash the plants were forced to assimilate soda. In this condition of things, the cotton plant could not be produced in its most perfect form."

Although this substitution is well recognized, many plant physiologists consider sodium as a non-essential element except for certain exceptional plants that normally grow along sea coasts or other salty soil habitats (1). Some of the so-called plant responses to sodium can probably be attributed to secondary effects such as changes in soil structure or substitution of sodium for potassium on the clay mineral which releases more potassium to the plant. Responses to this element are frequently reported under conditions of low potassium supply (2, 3). When potassium supplies are adequate, sodium responses are not as frequent, but some responses have been obtained on cotton plants that were considered to be adequately supplied with potassium and other nutrients. (4).

In the winter of 1949-1950 a preliminary experiment was conducted in the greenhouse using virgin Leon fine sand in which white clover and Pangola grass were grown together in 2-gallon pots with adequate fertilization and lime except that in certain of the cultures one-third, two-thirds, and all of the potassium was replaced by equivalent amounts of sodium. It was observed that the clover was progressively poorer on the higher sodium levels and developed the usual symptoms of potassium deficiency while the Pangola grass grew well over the entire range of sodium levels and actually produced more dry weight on the all-sodium level, although this was attributed to the lack of competition from the clover.

Since many Florida soils in pastures were known to be inadequately supplied with potassium, two pot experiments were planned (Table 1) to investigate the substitution of sodium for potassium in Pangola grass more thoroughly. The first experiment was designed to show responses to potassium levels and to chemically equivalent quantities of sodium supplied alone and with potassium. The second experiment was designed to show the effects of sodium, potassium, calcium, and ammonium as cations when equivalent amounts of nitrogen were supplied as top dressings to pastures that had been fertilized at slightly better than average

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rates. The effects of rates of lime and high calcium supplied as calcium chloride were also included in this experiment. Demineralized water applied to the surface of the pots was used throughout the experiment.

TABLE 1.—Pangola Grass, Greenhouse Experiments, Winter 1950-1951.

Experiment I. Substitution of Na for K.

Basic treatment in 2 gal. pots of virgin Leon fine sand 0-6 inch.
2000 lbs. lime/A = 7.3 gms. dolomite/pot.
500 lbs. superphosphate/A = 1.8 gms. superphosphate/pot.

Na and K variations (3 Replications):

1. 0 lbs. K/A + 0 lbs. Na/A = 0 gms. KCl + 0 gms. NaCl/pot.
2. 0 lbs. K/A + 78 lbs. Na/A = 0 gms. KCl + .27 gms. NaCl/pot.
3. 0 lbs. K/A + 157 lbs. Na/A = 0 gms. KCl + .54 gms. NaCl/pot.
4. 100 lbs. K/A + 0 lbs. Na/A = .35 gms. KCl + 0 gms. NaCl/pot.
5. 100 lbs. K/A + 78 lbs. Na/A = .35 gms. KCl + .27 gms. NaCl/pot.
6. 100 lbs. K/A + 157 lbs. Na/A = .35 gms. KCl + .54 gms. NaCl/pot.
7. 200 lbs. K/A + 0 lbs. Na/A = .7 gms. KCl + 0 gms. NaCl/pot.
8. 200 lbs. K/A + 78 lbs. Na/A = .7 gms. KCl + .27 gms. NaCl/pot.
9. 200 lbs. K/A + 157 lbs. Na/A = .7 gms. KCl + .54 gms. NaCl/pot.

Nitrogen to be supplied as required as NH_4NO_3 at same rates and times as Experiment II.

Experiment II. Na, K, Ca, and NH_4 as cations in nitrate applications.

Treatments in 2 gal. pots of virgin Leon fine sand 0-6 inch.
500 lbs. superphosphate/A = 1.8 gms. superphosphate/pot.
150 lbs. muriate of potash/A = .52 gm. KCl/pot.

Variations (2 Replications)—each variation to get separate top dressings of Na, K, Ca, and NH_4 nitrates, nitrogen to be equivalent to 100 lbs/A $NaNO_3$.

0 lbs. lime/A = 0 gms. $CaCO_3$/pot.
2000 lbs. lime/A = 7.3 gms. $CaCO_3$/pot.
4000 lbs. lime/A = 14.6 gms. $CaCO_3$/pot.
100 lbs. $CaCl_2$/A = 3.6 gms. $CaCl_2$/pot.

5 ml/pot of the following solutions are N equivalent of 100 lbs/A $NaNO_3$
73 gms. $NaNO_3$/L
96 gms. KNO_3/L
35 gms. NH_4NO_3/L
88 gms. $Ca(NO_3)_2 \cdot 4H_2O$/L

Log of Experiments.

Basic fertilizer put in pots and plants started December 15-16, 1950.
Plants established at 5 sprigs per pot thru January 8, 1951.
First N application and 1 ml. Hoaglands A to Z minor element soln. January 8, 1951.
First cutting 2-5-51.
Second N application 2-8-51.
Second cutting 3-2-51.
Third N application 3-2-51.
Third cutting 4-2-51.
Fourth N application 4-2-51 (double rate of application).
Fourth cutting 5-8-51.
Fifth N application 4-9-51 (double rate of application).
Fifth cutting 6-19-51 (experiments terminated).
Soil samples taken from pots 7-27-51 (R-1122).

The grass was cut back to the level of the top of the pots (about one inch above soil surface) once a month and nitrogen reapplied at a rate equivalent to 100 pounds per acre of nitrate of soda. After the third cutting it was obvious that this rate of nitrogen was inadequate to take care of the rapid rate of growth and the nitrogen application was doubled.

TABLE 2.—Pangola Grass Na-K Experiments - Greenhouse 1950-51. Total Yields of Five Cuttings in gms./pot.

Experiment I

Treatments	0 Na	1 Na	2 Na	Totals K
0 K	16.97	23.96	36.98	
	14.66	21.85	24.63	
	15.28	22.91	23.55	
	46.91	63.72	85.16	200.79
1 K	24.46	32.04	40.31	
	26.99	38.99	36.59	
	28.13	32.31	34.45	
	79.58	103.34	111.35	294.27
2 K	33.45	40.10	43.55	
	37.60	39.63	46.12	
	34.47	38.51	48.23	
	105.52	118.24	137.90	361.66
Totals Na	232.01	290.30	334.41	

L.S.D. for Na and K totals = 41.84 at 1% level.
(gms./pot x factor 275 = lbs./acre.)

Experiment II

Treatments	0 Lime	1 T Lime	2 T Lime	1000 Lbs. $CaCl_2$	Total NO_3 Carriers
KNO_3	60.59	58.18	67.07	61.66	
	57.79	60.02	66.39	69.40	
Sums	118.38	118.20	133.46	131.06	501.10
$NaNO_3$	48.27	52.54	48.52	46.48	
	53.25	58.44	52.37	50.87	
Sums	101.82	110.98	101.39	97.35	411 24
$Ca(NO_3)_2$	44.64	34.78	35.91	26.53	
	32.08	35.53	38.61	25.74	
Sums	76.70	70 31	74.52	52.27	273.80
NH_4NO_3	35.06	34.36	33.10	28.02	
	37.21	35.81	38.59	27.33	
Sums	72.27	70.17	71.69	55.35	269.48
Totals Lime	368.87	369.66	381.06	336.03	

L.S.D. for NO_3 carrier and lime totals 40.47 at 1% level.
29.22 at 5% level.

L.S.D. for interaction sums 20 23 at 1% level.
14.61 at 5% level.

The rates of growth in the first experiment followed the rates of potassium and sodium application very closely from the start. Characteristic potassium deficiency symptoms, thin stems, narrow leaves and burning of the lower leaves, appeared almost at once in the pots receiving no potassium or sodium and developed progressively through the potassium and sodium levels so that these symptoms were present in the high sodium-potassium culture at the final cutting. Unusually early bloom was also noted in the pots receiving no potassium or sodium. The yield summary in Table 2 shows that under the conditions of the experiment sodium and potassium both caused highly significant yield increases. No significant interaction of sodium and potassium was found under the conditions of this experiment. It is possible that the increases in dry weight due to sodium and potassium are mutually additive.

In the second experiment there was little difference in the growth of the first two cuttings except that there was some lag in the calcium chloride pots. The high salt content in these pots made it difficult to get the grass sprigs to root and this slow start resulted in reduced yields which may not be directly comparable to the lime and check treatments. The early clippings removed much of the original potassium application and in the last three clippings the yield pattern was much the same as shown for total yields in Table 2. In later cuttings the $Ca(NO_3)_2$ and NH_4NO_3-treated plants developed characteristic potassium deficiency symptoms of thin stems and narrow leaves and burning of the lower leaves. The $NaNO_3$-treated plants continued to produce thick stems and broad leaves of normal plants but prior to the last cutting developed potassium deficiency symptoms which appeared as a lighter shade of green over the entire plant and some lower leaf burn. Normal growth continued on the KNO_3-treated plants.

As a dry weight producer KNO_3 was a superior top dressing for Pangola grass, $NaNO_3$ gave about 20 percent less, whereas $Ca(NO_3)_2$ and NH_4NO_3 produced only about one-half the dry weight of the KNO_3 treatment. Lime levels had little effect on dry weight production although some depression was caused by $CaCl_2$ on the $Ca(NO_3)_2$ and NH_4NO_3 treatments.

Chemical analyses for potassium, sodium, calcium and phosphorus in the last cutting are given in Table 3. The potassium and sodium supplies in the first experiment were nearly exhausted although the pattern of sodium and potassium application was still reflected in the quantities of these elements in the plant tissue. Calcium, magnesium, and phosphorus values are approximately inversely proportional to the amount of dry weight produced at this cutting.

In the second experiment the effects of the extra sodium and potassium are clearly apparent. High potassium depressed sodium, calcium, and magnesium content in the herbage and high sodium depressed potassium, calcium, and magnesium. The $NaNO_3$ applications did not depress the calcium content of the herbage to the same extent as equivalent applications of KNO_3 in this cutting. In earlier cuttings the depression of calcium by KNO_3 and $NaNO_3$ were of the same order of magnitude. (It was necessary to analyze the plant tissue from the $NaNO_3$ treatments for calcium by the oxalate method because the high sodium content interferes in the flame photometer procedure.) The phosphorus values again seem

largely to reflect the rate of growth. the KNO_3-treated plants containing the least and the NH_4NO_3-treated plants containing the most phosphorus.

TABLE 3.—Pangola Grass Na-K Experiments, Greenhouse 1950-51 Analysis of Fifth Cutting Composite Expressed as mg/gm Dried Tissue.

Experiment I

Treatment K	Treatment Na	Sample No.	K	Na	Ca	Mg	P
0	0	P-434-1	3.8	2.0	13.0	4.50	2.25
0	1	2	1.9	2.3	12.5	2.10	1.95
0	2	3	2.5	4.3	11.8	2.28	1.26
1	0	4	3.3	1.5	11.0	3.30	1.70
1	1	5	2.5	2.0	11.8	2.28	1.10
1	2	6	2.5	3.5	10.3	1.63	1.03
2	0	7	3.3	1.5	10.3	3.30	1.20
2	1	8	3.3	2.5	9.5	2.85	1.03
2	2	9	2.5	4.8	8.8	1.93	.83

Experiment II

Lime							
0	K	29	16.3	1.3	2.5	1.00	.60
0	Na	30	2.5	15.3	6.3	.88	.98
0	Ca	31	3.8	1.8	10.3	2.85	.93
0	NH_4	32	3.3	1.3	4.8	4.00	1.33
1	NH_4	33	2.5	1.5	11.8	4.00	1.33
1	Ca	34	3.3	1.3	11.0	3.52	1.10
1	Na	35	3.3	12.5	6.5	1.15	.70
1	K	36	16.3	1.3	3.0	.88	.45
2	Ca	37	3.3	1.3	10.3	2.85	.85
2	K	38	14.5	1.0	2.5	.88	.45
2	NH_4	39	3.3	1.8	11.8	2.85	1.10
2	Na	40	1.9	14.3	6.3	1.00	.70
Cl	Na	41	2.5	18.5	7.0	1.00	.98
Cl	NH_4	42	4.4	2.0	8.8	1.93	3.32
Cl	K	43	16.8	1.3	2.5	.88	.55
Cl	Ca	44	4.4	2.0	10.3	1.48	2.80

Analyses of the earlier cuttings are not tabulated here but similar trends were noted. As would be expected the earlier the cutting the higher the sodium and potassium percentages. It was evident that some luxury consumption of sodium and potassium in the early cuttings resulted in an early depletion of these elements in the soil and subsequently reduced dry weight production in later cuttings.

Soil analyses at the end of the experiments showed less than 10 ppm. each of sodium and potassium present in all pots except where these elements had been added with the nitrate. Residues of sodium and potassium, where these elements had been applied in the top dressing, were variable, ranging from 10 to 60 ppm. of the element applied. Minimum exchangeable calcium in the no-lime pots at the end of the experiment was 230 ppm.

Table 4 shows the effects of these treatments on the nitrogen content of the herbage. The trend is toward a lower percentage of nitrogen in the herbage with increased growth. Nearly all the nitrogen added was

TABLE 4.– Pangola Grass Na-K Experiments, Greenhouse 1950-1951.

Treatment		Sample	Percent Nitrogen in Oven Dried Herbage				Total N Removed in mgs. per Pot				
K	Na	No.	1st & 2nd Cutting P-409	3rd Cutting P-413	4th Cutting P-426	5th Cutting P-434	1st & 2nd Cutting P-409	3rd Cutting P-413	4th Cutting P-426	5th Cutting P-434	Grand Total
Experiment I											
0	0	1	.....	1.50	2.20	2.01	.....	59.5	46.9	125.8	232.2
0	1	2	2.43	1.03	1.77	1.36	129.8	59.3	46.4	171.1	406.6
0	2	3	3.34	.95	1.44	1.47	186.9	58 6	70.9	176.6	493 0
1	0	4	2.52	.90	1.41	1.57	147.0	61.0	52.3	160.1	420.4
1	1	5	2.12	.85	.93	1.06	144.9	55.9	62.2	152.1	415.1
1	2	6	2.45	.85	.90	1.01	153 0	64.0	76.7	149.8	443.5
2	0	7	1.78	.79	.90	1.10	113.0	60.1	67.0	151.5	391.6
2	1	8	2 27	.75	.86	.95	144.5	64.5	88.7	134.3	432.0
2	2	9	2.30	.79	.75	.70	157.8	65.8	80.4	140.5	444.5
Experiment II											
Lime											
0	K	29	1.99	.80	.76	.48	146 0	56.4	95.4	154.9	452.7
0	Na	30	2.14	.79	.74	.70	138.8	58.4	100.7	166.0	463.9
0	Ca	31	2.58	1.00	1.08	.84	192.8	63.5	54.7	163.5	474.5
0	NH_4	32	2.31	.83	1.12	.85	157.0	53.8	68.7	142.2	421.7
1	NH_4	33	1 90	.78	1.04	1.08	104.3	57.3	69.1	168.6	399 3
1	Ca	34	1.84	.76	.89	1.02	96 0	50.2	75.2	152.0	373.4
1	Na	35	1.96	.87	.80	.73	188.7	54.4	80.5	215.8	539.4
1	K	36	2.29	.79	.81	.52	165.9	65.8	100.9	161.7	494.3
2	Ca	37	1.82	.86	.84	.78	110.2	45 9	62.4	143.9	362.4
2	K	38	2.12	.82	.76	.46	172.3	65.2	105.1	169.2	511.8
2	NH_4	39	2.10	.78	1.07	1.00	122 2	52.9	73.4	163.8	412.3
2	Na	40	2.14	.78	.92	.73	143.8	68.5	105.7	188.9	506.9
Cl	Na	41	2.38	.84	.82	1.01	118.2	74 2	101.2	237.8	531.4
Cl	NH_4	42	2.69	1.01	1.74	2.00	119.7	98.5	97.3	157.8	473.3
Cl	K	43	2.31	.86	.73	.44	126.3	93.6	113.9	147.9	481.7
Cl	Ca	44	2.50	.97	1.43	1.47	105.8	68.2	70.6	146.1	390.7
			Nitrogen added per pot in mgs.				120	60	120	120	420

recovered in the herbage even under acute potassium deficiency and some additional nitrogen was recovered from the soil under the optimum conditions of the experiment.

CONCLUSIONS

Under greenhouse conditions sodium will substitute for a large percentage of the potassium requirements in Pangola grass. Because of the usual low level of available potassium and sodium during the summer months in Florida soils under pasture conditions it is probable that at least on Pangola grass more dry weight per pound of nitrogen fertilizer used will be obtained if sodium or potassium or both are applied with the nitrogen. The percentage nitrogen in the herbage may be controlled to a limited extent by the quantities of sodium and potassium applied with the nitrogen or available in the soil at the time of the nitrogen application.

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SYMPOSIUM: SOURCES AND RATES OF LIMING

GEOLOGY AND LOCATION OF LIME SOURCES IN FLORIDA

J. L. Calver*

Limestone production statistics are gathered annually by the U. S. Bureau of Mines in cooperation with the Florida Geological Survey. The latest data available, those for the year of 1949, show that commercial limestone was produced from forty quarries located in eleven counties in Florida. In distribution these counties fall naturally into four areas, with Jackson County representing the northwestern portion of the State, Alachua, Levy, Marion, Citrus, Sumter, Hernando and Pasco counties representing the central portion and, in South Florida, dolomite in Sarasota and Manatee counties on the northwest and limestone in Dade and Broward counties on the southeast. These forty quarries, for which data were submitted to the U. S. Bureau of Mines, produced over 4,200,000 short tons of limestone in 1949, which had a value in excess of $4,700,000.

The use in which the greatest tonnage of limestone was consumed is classified under the heading: *concrete and road metal.* For these purposes, 3,067,000 short tons valued at approximately $3,510,000 were sold during 1949, and that quantity represents 73 per cent of the total crushed limestone production. The remaining 27 per cent was divided approximately as follows: *Railroad ballast* consumed nearly ten per cent; *road base* materials eight and one-half per cent; and *non-commercial* uses—that material produced by county and city units and used primarily for road base and road metal—amounted to less than five per cent. Thus the limestone entering into concrete, road metal, railroad ballast and road base uses accounts for approximately 97 per cent of the entire production of crushed limestone. Agricultural limestone, riprap, fertilizer filler and other minor uses shared in only three per cent of the State's total production. The exact totals for these uses are not available because of the policy adopted by the U. S. Bureau of Mines to avoid disclosure of production data from individual operations.

The quantity of limestone used in the manufacture of cement, together with that entering into the production of burned lime have been excluded from the before-mentioned production data. The tonnage and value of limestone for these purposes normally are included in data on cement and lime production. These industries, however, have only one or two producers in the State and, unless each company gives its approval, disclosure of the individual company's production data is avoided. It may be interesting to mention, nevertheless, that about 8 per cent of the hydrated lime manufactured in the State in 1949 was consumed in agricultural uses.

With this introduction, I would like to outline briefly the geology of the State and to point out in particular the relationships found in the limestone-producing areas already briefly mentioned and shown in quite a generalized way on the map of figure 1.

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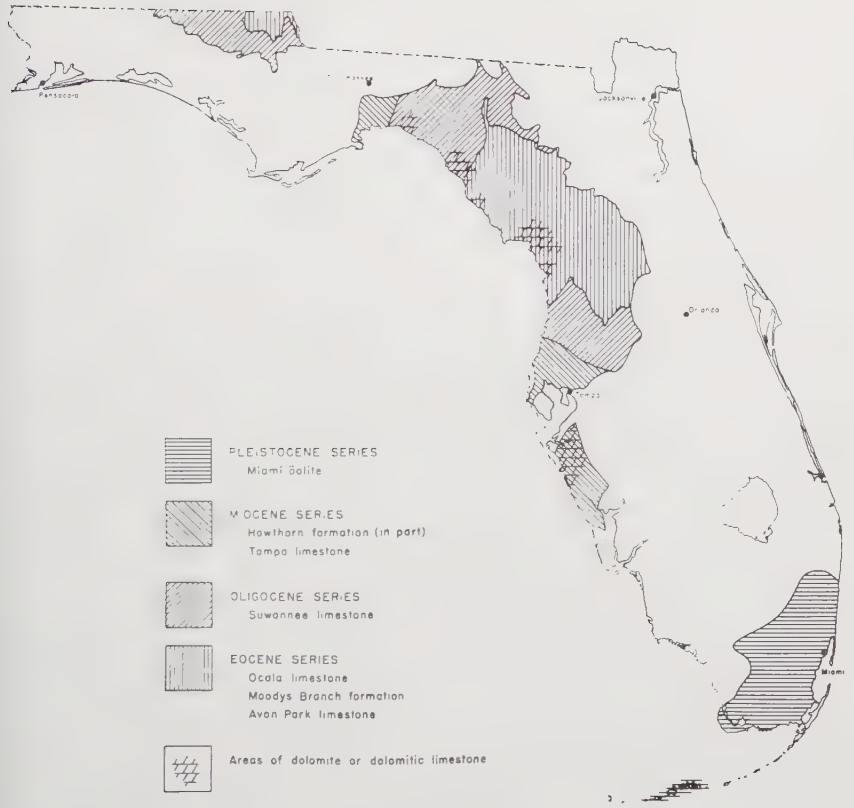

Figure 1.—Generalized map showing surface distribution of various limestones and dolomites in Florida.

Situated wholly within the Coastal Plain Province, Florida is underlain by 4,000 feet or more of sedimentary rocks that overlie a basement of older sedimentary, metamorphic and igneous formations. The oldest rock exposed at the surface of the State is considered by geologists to be quite young; it is the Avon Park limestone of Middle Eocene age. This formation, together with the Ocala limestone, Upper Eocene, and the still younger formations of the Oligocene, Miocene, Pliocene, Pleistocene and Recent Epochs represent a stratigraphic section of approximately 1,800 feet. Sedimentary rocks older than the Middle Eocene limestones do not crop out and are known in Florida only through cuttings, cores, and records of wells that penetrate them. These subsurface formations include the rocks assigned to the Lower Eocene, Paleocene of the Cenozoic system, as well as those of the Mesozoic, Paleozoic and Pre-Cambrian systems.

The early Cenozoic and Mesozoic formations range in thickness from 2800 feet in the northern part of the Peninsula to more than 15,000 feet in the region of the Florida Keys. In Western Florida, these formations are somewhat thicker and range from 8,400 feet in Jackson County to an estimated 15,000 to 20,000 feet in Escambia County. The older subsurface

strata of the Paleozoic system are not less than 3,000 feet in thickness and may be as much as 6,000 feet. Because all of these older sediments, as well as the crystalline rocks of possible Pre-Cambrian age do not come to the surface anywhere within the State, the sequence of events that make up their history is not of primary interest to either the producers or the consumers of limestone which is obtained from quarries in the surface formations. Furthermore, the structures developed in the Cretaceous and older rocks bear little, if any, relationship to the structures in the younger sediments that have been outlined by surface studies and detailed by well penetrations.

There are several structures in the uppermost and younger sedimentary rocks of the Floridian Plateau that are significant in bringing limestone formations near the land surface. The most important of these is the Ocala Uplift in which the Eocene and younger sediments are arched into a broad doubly plunging anticline that trends northwest-southeast. This fold may be traced from Madison County southward to Hardee County. It is along the crest of this fold in the central and southern portions of Levy County that the Avon Park limestone, the oldest sedimentary rock exposed in Florida, is found. Surrounding the outcropping of this chalky limestone are other Eocene limestones: the Moodys Branch formation and the Ocala limestone. The Moodys Branch formation is a nearly pure limestone of about 80 feet in thickness that has been separated from the base of the Ocala limestone, which has a maximum thickness of 360 feet, in recent studies by the Florida Geological Survey. These Eocene formations on the flanks of the fold dip at low angles toward the Atlantic Ocean and the Gulf of Mexico. It is this broad, gentle arch known as the Ocala Uplift that brings the Eocene limestone close to the land surface in the central part of the State.

At many places within this anticlinal structure in Alachua, Levy, Marion, Citrus, Sumter and Hernando counties, the Ocala limestone has been extensively quarried, particularly in the vicinity of Ocala. For the most part this limestone has a uniform texture that allows ready crushing and pulverizing; it is generally free from grit and its chemical purity approaches that of the chemical formula for the mineral calcite, i.e., 100 per cent $CaCO_3$. The Ocala limestone will meet the most exacting chemical specifications for high calcium stone. In spite of its purity, this limestone enters into many common uses which include road base material, road metal, railroad ballast, agricultural lime, concrete aggregate, etc. It is also used in the manufacture of quick and hydrated lime.

Because of the southward regional dip of the rock strata, the Eocene limestones are not found exposed south of the Hernando-Pasco county-line. In these counties, limestone formations that occur above the Ocala limestone, the Suwannee limestone of Oligocene age and the Tampa limestone of Miocene age, are found near the land surface. The Suwannee limestone varies in character from a hard, resonant limestone to a soft, granular limestone that contains some silica; the Tampa limestone also may be hard and massive and contain impurities of clay and sand. Both of these formations have been quarried so extensively in the vicinity of Brooksville, Hernando County, that the name "Brooksville Stone" is often used to designate these limestones which are used for cement manufacture, railroad ballast and concrete aggregate.

Further to the south in Manatee and Sarasota counties, Miocene strata contain limestones belonging to the Tampa limestone and the Hawthorn formation. Outcrops of these formations, particularly in the western portions of the counties, are here composed of dolomite or dolomitic limestone. Agricultural lime is produced in the vicinity of Samoset, Manatee County, and of Sarasota, Sarasota County, from dolomitic limestones that are early or possibly middle Miocene in age.

Dolomite and dolomitic limestones are also found in Dixie, Levy, and Citrus counties. The upper portion of the Avon Park limestone is represented in some areas by dolomitic rock and the quarry at Lebanon, Levy County, is in a dolomite facies of this formation. In northern Citrus County, the Moodys Branch formation contains some poorly consolidated dolomitic rock which is quarried in the vicinity of Red Level. Dolomites and dolomitic limestones also occur in western Dixie and southern Taylor counties as a facies of the Ocala limestone; however, quarries have not been developed in these areas.

In western Florida, there is another gentle fold in the series of younger sediments that form the surface rocks of the State. This structure passes into Jackson County and is the southern extension of an anticline known as the Decatur Arch. The middle Eocene limestones are again brought to or near the land surface in Jackson, Holmes and Washington counties, and the Ocala limestone is quarried in Jackson County. Huge reserves of high grade limestone exist in not only Jackson County, but also in Holmes and Washington counties, and structurally the area is quite similar to that of the Ocala uplift.

The remaining limestone sources in the State, particularly those in South Florida, are very young, geologically speaking. They were formed, for the most part, during the Ice age or Pleistocene epoch. From a commercial quarrying point of view, the most important of the several formations that have been mapped in southern Florida, is the Miami oolite. Generally, this formation is a comparatively soft, white limestone composed of small spherical grains called oolites. It is found at or near the land surface in a broad band that extends along the East Coast from approximately the Palm Beach-Broward county-line to Key West. This rock is quarried extensively in the vicinity of Miami where it is the main source of commercial limestone. The crushed limestone produced in Dade County constituted more than 55 per cent of the crushed stone produced in Florida during the year of 1949.

This discussion of lime sources in Florida would be incomplete without mention of the shell facies of the Anastasia formation. This Pleistocene formation is found at or near the surface in a narrow belt along the East Coast from Anastasia Island, St. Johns County, to near the Palm Beach-Broward county-line where it may be traced into a transitional zone of shell marl and sandy limestone that merges southward into the Miami oolite. The most conspicuous part of the Anastasia formation is coquina, a rock composed of whole or broken shells that are more or less firmly cemented together. It is well known that the harder portions of coquina rock make an attractive and durable building stone and that the softer portions, which may contain considerable quartz sand, are used for concrete aggregate, in the manufacture of concrete products and in road building. Crushed coquina has been used in the past for agricultural lime and pulverized coquina for stock feed and chicken grit. A large

and extensive utilization of coquina will begin with the operation of the new cement mill located near Flagler Beach, Flagler County. Here the Lehigh Portland Cement Company now has under construction a cement mill which has a designed capacity of 1,400,000 barrels annually.

LIMING MATERIALS

GAYLORD M. VOLK *

Liming materials are used for the counteraction of excess soil acidity. Ground limestones are used to the greatest extent for this purpose, with hydrated lime next in volume. A limited amount of burned or quick lime, soft marl, shell marl, quarry run soft lime rock, and certain industrial by-products are used locally or for special purposes.

Ground agricultural limestone can be classified either as high calcic limestone or as dolomite in most instances. High calcic limestone usually contains 85 to 100 percent of calcium carbonate with somewhat less than 10 percent of magnesium carbonate present. The dolomite consists of a mixture of calcium carbonate and magnesium carbonate in which the calcium carbonate makes up not over 63 percent of the carbonates and the magnesium carbonate between 37 and 46 percent. There are no established limits for these materials, but naturally occurring limestones more or less fall into such a grouping. When limestones were deposited in past geologic times, two ranges in the calcium carbonate-magnesium carbonate predominated. At one end of the range the high calcic limestones containing less than 10 percent of magnesium carbonate were deposited. Beyond this there was a big jump in the ratio of calcium to magnesium and the next range of deposition came where magnesium carbonate made up from 37 to 46 percent of the carbonates present. Above this there was very little deposition of limestone in any form. Table 1 shows how well this system is substantiated by materials submitted for sale in Florida.

TABLE 1.—REPRESENTATIVE ANALYSES OF AGRICULTURAL GROUND LIMESTONE USED IN FLORIDA IN 1950.

(From eight different sources in Florida, Georgia and Alabama)

Calcium Carbonate %	Magnesium Carbonate %	Moisture %	Passing 60 Mesh %	Passing 20 Mesh %
High Calcic Limestone				
89		2	42	78
92		3	31	49
92		1		
Dolomite				
51	37	5	63	85
54	41	1	65	85
56	37	3	70	87
58	36	2	74	87
59	35	2	55	73

The Commercial Fertilizer Law of Florida states as follows: "Limestone shall be guaranteed on the basis of Calcium Carbonate ($CaCO_3$) and

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Magnesium Carbonate ($MgCO_3$) and in addition shall be guaranteed on a screen test."

The screen test consists of determining the percentages of the material that will pass 60 mesh and 20 mesh sieves, and is so reported on the tag. The finer the material, the more rapid is its reaction with the soil. Fine materials can be made to come in contact with a greater portion of the soil mass and react more completely with the soil acidity. Coarse particles will neutralize the acidity in their immediate vicinity and must then wait either for tillage to rearrange them against fresh soil or for the slow reaction with acidity lying at a distance to take place. Generally it is not desirable to have all very fine material, but to have a graded material containing a range of particle sizes. The coarser material that will react more slowly will continue to maintain the soil pH as new acidity develops from fertilization and associated practices. This permits heavier, more economical applications at one time without increasing the danger of overliming. Agricultural limestone usually has a fineness such that about 85 percent passes a 20 mesh and 60 percent passes a 60 mesh sieve. This makes a good mixture of particle sizes for general use. Finer grades often are called "Pulverized" and "Superfine", and coarser grades called "Meal" and "Screenings." As can be seen from Table 1, ground dolomite submitted for test in Florida has a screen test about as given above for ground agricultural limestone. Our high calcic limestone derived from soft rock formations is somewhat coarser by screen test. This probably is a desirable difference between the materials because high calcic limestone reacts faster than dolomite.

Schollenberger and Salter (1) have published an evaluation chart for ground limestone intended to show how much of the applied lime would be used by the soil in a given period of time. According to the chart the materials listed in Table 1 would have approximately the following activities:

EFFICIENCY

(Amount used by soil acidity)

Time	*Dolomite*	*High Calcic*
3 months	42%	48%
1 year	67%	69%
4 years	80%	78%
16 years	85%	82%

It is assumed that the above values were obtained on soils of about a silt loam texture, and are the result of addition of a reasonable application to an acid soil.

Tests by Volk and Bell (2) showed that about one-third of a high calcic lime was used by soil acidity the first year after incorporation in three highly acid flatwoods soils. The amount of lime applied was sufficient to bring the pH up to 6.0 in one year. It was incorporated in the six inch surface layer of soil and kept undisturbed after incorporation. This rate is about one-half of that to be expected from the chart mentioned above.

Much lime is now being used for surface application to pastures. The rate of penetration is important because this markedly influences nitrification and retention of other fertility elements as well as supplying calcium.

Tests showed no significant differences in rates of penetration of high calcic limestone, dolomite, or hydrated lime. Penetration into acid soil was very slow. When a heavy application of lime was applied only to the surface instead of being incorporated, it raised the pH of the immediate subsurface at the one inch depth only two-tenths of a pH unit. This same amount of lime incorporated throughout the surface six inches would have raised the soil pH from the virgin pH of about 4.3 up to approximately pH 6.1. From this it is estimated that lime will not effectively penetrate over one inch per year regardless of the source used. Apparently the pH of a layer of soil must be 6.0 to 6.5 before lime will neutralize deeper layers below it.

Hydrated lime and quick lime, made by burning high calcic limestone, have a neutralizing value such that about 1500 pounds of hydrate or 1100 pounds of quick lime are equal to a ton of high calcic lime. They react very rapidly with the soil. In addition to the above there are two products obtained by burning dolomite. One product sold in the oxide form contains about 42 percent magnesium oxide and 58 percent calcium oxide. The other is similar except that the calcium oxide has been converted to hydrated lime but the magnesium remains as the oxide. These materials are for special uses where quick action and a source of magnesium are desired. The availability of the magnesium apparently lies between that of soluble magnesium and dolomite.

Shell refuse, shell marl, soft marl, and by-product lime from water treatment all are good liming materials if applied dry and in accordance with their screen tests. Cyanamid and basic slag have liming value, but their cost must be borne largely by the need for the other elements carried. Raw rock phosphates have negligible liming value.

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EFFECTS OF LIME ON PLANT NUTRIENT EFFICIENCY

William K. Robertson *

The effects of lime on the physical properties of the soil are not as important in Florida as elsewhere because of the sandy nature and the low clay content of Florida soils. However, liming may affect the availability of plant nutrient elements in these soils by chemical reaction and microbiological activity. The pH determination is used to evaluate the effect of lime on soil acidity since in normal soils calcium is the principal element on the base exchange complex.

In heavy clay soils the nearer the reaction is to neutral the more favorable in general are the tilth, permeability and friability of the soil. Maximum crop growth cannot be obtained unless these properties are at their optimum for root feeding. Highly acid or highly alkaline conditions promote puddling and impermeability which decrease root penetration and nutrient uptake.

Although all plant nutrient elements are of equal importance for optimum plant development, the much talked of major elements, nitrogen, phosphorus and potassium, followed by the equally important minor elements, molybdenum, boron, zinc, copper and manganese, will be considered in the order mentioned. Other elements known to be essential for nutrient balance will not be discussed because of the small amount of information available at this time.

Nitrogen

A large fraction of applied nitrogen may not be utilized by the crop but actually lost. If nitrogen is applied as the nitrate it dissolves readily in the soil solution and losses are predominantly in the drainage water. If nitrogen is applied in the ammonium form, it may be oxidized to nitrates and subjected to leaching, leached out as ammonia or volatilized as ammonia. In the latter case calcium level (pH) plays a very important role in determining the amount of applied nitrogen that is available to the plants.

Volk and Bell (18) treated seven Florida soils with ammonium nitrate and subjected them to leaching. They found where the exchange capacity was high, ammonia lost in the drainage water and that lost by volatilization was negligible up to pH 7.2. It was also found by other workers (6) that heavy soils could retain 95 to 100 percent of the nitrogen in anhydrous ammonia even when 600 pounds of nitrogen per acre were applied.

On acid soils of low exchange capacity quite different results were obtained. In the same experiment mentioned above, Volk and Bell (18) found that sandy soils lost considerable ammonia by leaching at low pH levels and little to none where the pH approached neutrality. Martin and Chapman (9) applied ammonium hydroxide to acid soils of low exchange capacity and found that when the pH was raised into the alkaline range, considerable ammonia was lost by volatilization.

From these data it would seem that in Florida where the rainfall is heavy, ammonium forms of nitrogen have an advantage over the nitrate

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form since they are less readily leached. However, the ammonium form should only be applied when the pH is higher than 5.5. If the pH is more acid than this, in addition to greater loss as ammonia, nitrification might not be adequate to supply the nitrate nitrogen plants need. The rate of nitrification of an ammonium source of nitrogen increases with the pH and is at a maximum between 6.5 and 7.5 (19). It is possible at these high pH levels that nitrification be so much in excess of plant requirement that the advantage due to the better retention of the ammonium form is soon lost.

Regardless of the source, ammonium or nitrate, the farmer should strive to apply his nitrogen at a time, in a place with relation to the roots and in a quantity such that there will be a minimum of delay between time of application and uptake by the plants.

Phosphorus

Acid conditions are not favorable for effective utilization of phosphorus. Neller and co-workers (10) applied 2000 pounds of rock phosphate to Immokalee fine sand, a flatwoods soil, and tested the effect of lime on phosphorus retention, in the upper 3 inches of soil, over a period of years. Their results shown in Figure 1 indicate that without lime one-half of the phosphorus was lost whereas with lime the loss was reduced to approximately one-eighth. They suggested that the added phosphorus was leached out of the surface layer in solution and in colloidal form. In the acid upland soils, where there are higher concentrations of iron and aluminum, phosphorus is fixed as iron and aluminum phosphate. Liming these soils converts the insoluble phosphates to the more readily available calcium phosphate. In many cases liming causes enough phosphate to be made available to restore normal growth (15). The increased availability of phosphorus due to lime may be partially attributed to the creation of more favorable conditions for microbial activity which make possible the conversion of organic phosphorus to available forms.

It has been found that insufficient quantities of lime do not increase phosphorus uptake to any extent. Robertson (14), growing Camellia oats on five different Florida soils did not get any significant difference in phosphorus uptake between application rates of 500 and 1000 pounds of lime per acre. Volk and Bell using Norfolk fine sand found that the Truog phosphorus did not vary much when the pH was raised to approximately 5.5 (18).

If the lime added is sufficient to raise the pH much over 7, more and more of the less soluble tricalcium phosphate begins to form and the plants may suffer for lack of phosphorus.

The most important groups of phosphate compounds present in soils in order of their availability are as follows: (1) Calcium and magnesium phosphate, (2) Organic phosphorus compounds (phytin, nucleotides and lecithin), (3) Iron and aluminum phosphates, and (4) Apatite (17). To create favorable conditions for the available forms of group 1 to occur it is necessary to lime to about pH 6.5. This is also within the range of optimum microbial activity which would convert group 2 to available compounds and it is above the pH at which the insoluble iron and aluminum phosphates occur in quantity. Since group 4 (apatite) is practically insoluble at any reaction at which plants grow, it need not be considered in connection with liming. From this it appears that calcium should be

added to acid soils to the extent that about 75 percent of the exchange capacity is saturated for maximum use of phosphorus.

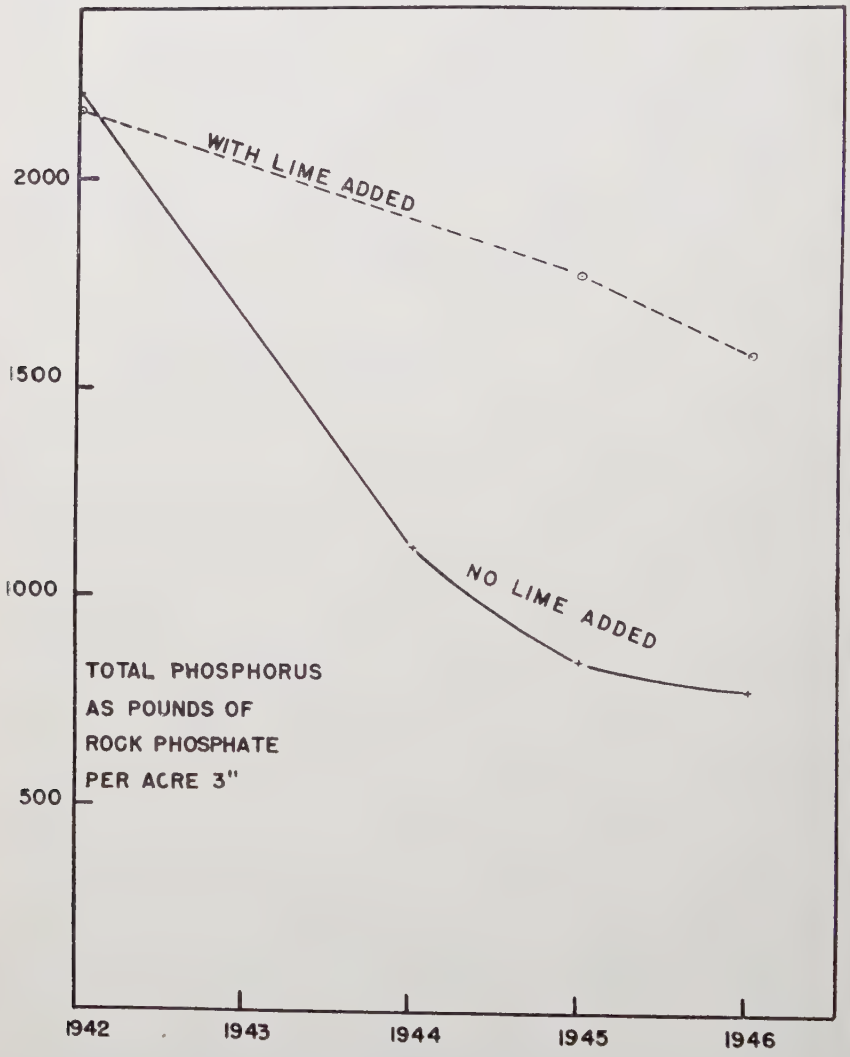

Figure 1.—Effect of liming an Immokalee fine sand pasture upon the rate of loss of phosphorus of rock phosphate from the surface three inches. Ground calcium limestone at one ton per acre was added in 1942 and again in 1943. Neller, Jones, Gammon, Nathan and Forbes (10).

When highly ammoniated superphosphate is used in mixed fertilizers with lime as a filler and when the fertilizer is stored for a month or more there results a conversion of the readily available mono-calcium and di-calcium phosphates to the less available tri-calcium phosphate. This conversion can be minimized by using ammoniated superphosphate with

a lower percentage ammoniation and by spreading the fertilizer immediately after mixing it with the lime.

Potassum

The most important sources of potassium for absorption by plants are: (1) directly from the fertilizer band, (2) from the soil solution, and (3) from the base exchange complex. The most permanent of these sources is from the exchange complex. This is because potassium in the fertilizer band, if not taken up by the plants, will go into solution and be subjected to adsorption on the base exchange complex; and potassium in the soil solution that cannot find a place on the base exchange complex will be leached out if not readily absorbed by the plants.

The amount of adsorption of applied fertilizer potassium on the base exchange complex is inversely proportional to the firmness with which the ions being replaced are held. According to the lyotropic series, hydrogen is held more firmly than calcium. On this account the chances of potassium finding a place on the base exchange complex would be considerably enhanced if calcium and not hydrogen was the prevalent ion. Volk and Bell (18) working with seven Florida soils, found that on an average the leaching loss of applied potassium was two and a half times as much at pH 5.5, and four and a half times as much at 4.0, as it was at 6.8. Their results are shown in Figure 2. It must be remembered, however, that added calcium will crowd potassium as well as hydrogen off the base exchange and it thus may be lost to the plants.

If the advantages due to greater fertilizer potassium being adsorbed and the disadvantages due to the loss of exchangeable potassium are weighed, it is quite possible that liming would be practiced as far as potassium is concerned for most of the acid soils of Florida. Some of the reasons for this conclusion are: 1. The tremendous loss by leaching and hence the need for large amounts of supplemental potassium. 2. The acid soils of Florida have generally a low exchange capacity and initially possess only a very small percentage of the potassium needed for increased yields.

Molybdenum

Very recent work at Hastings, Florida, on cauliflower indicated that molybdenum deficiency of soils could be averted either by liming or by the addition of molybdenum (3). Other workers have obtained similar results with other crops (5). Oertel et al (11), working with subterranean clover in Australia, found that liming increased the availability of molybdenum up to pH 7; and Evans and his co-workers (4), found a close relationship between pH value of soils and the molybdenum content of alfalfa grown on them. At low pH values they obtained increased yields for molybdenum but responses at high pH values were less pronounced. Evans et al (4), also found that the molybdenum content of alfalfa from naturally neutral or slightly alkaline New Jersey soils was very low and they suggested that molybdenum had been lost by leaching at the high pH values that occurred during the soil forming process.

From this it appears that at least part of the molybdenum forms some insoluble compound in acid soil which in the presence of lime becomes soluble. The possibility of leaching in highly limed soil should be considered.

Boron

Jones and Scarseth (7) were among the first to stress the importance of a proper Ca/B ratio for plants. They found the ratio for oats and tobacco to be 200 to 1 and 1200 to 1, respectively, and if the ratio decreased boron toxicity would occur. Lorenz (8) working with beets

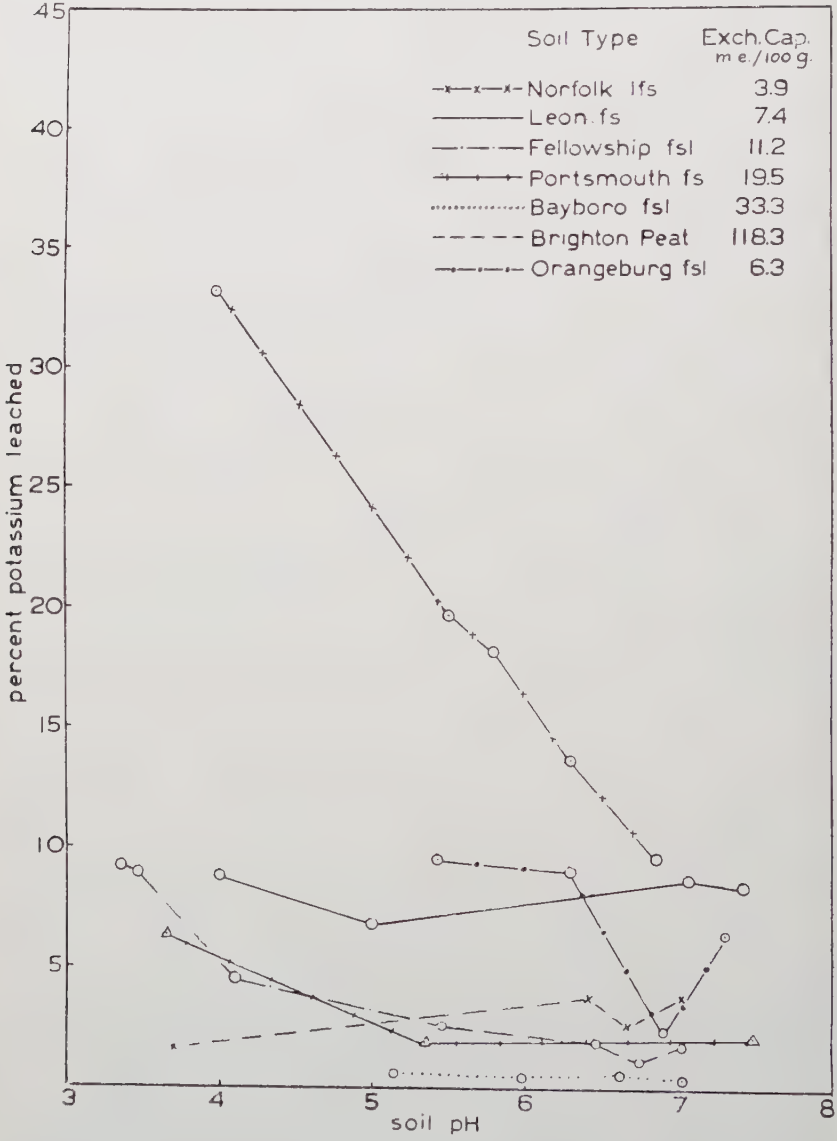

Figure 2.—Effect of soil pH on the retention of potassium against leaching. Treatment: 9-inch soil profile in 4-gallon lysimeters treated with NH_4NO_3 and K_2SO_4 in solution at rates of 570 and 370 pounds per acre, respectively, and leached 36 hours to deliver 2½ inches of leachate. Volk and Bell (18).

found that additions of calcium to boron-toxic soils would alleviate boron toxicity and he suggested that this was due to the restoration of the proper Ca/B ratio. Purvis and Hanna (13) were able to restore normal growth to boron deficient plants on over-limed soils by adding a source of available boron.

TABLE 1.—Influence of Long Established Reaction Levels in Lakeland Fine Sand Upon the Level of Native and Applied Water-Soluble Boron (as ppm. B) in Air-Dried Soil.

Soil Treatment	pH Levels **					
	5.27	5.20	5.44	6.39	6.63	7.01
Native soil boron after 20 years (ppm. boron)	0.08*	0.06	0.09	0 10	0.10	0.16
4 months after 200 lbs. borax per acre (ppm. boron)	0.27	0 28	0.69	0.61	0.66	0.95
12 months after 200 lbs. borax per acre (ppm. boron)	0.20	0.17	0.17	0.19	0.22	0.36

* Tests made on 0-6 inch depth.

** 5.27 and 5.20 obtained by adding sulfur; 5.44 was normal pH; and the soils having pH levels of 6.39, 6.63 and 7.01 received lime.

Winsor (20, 21), working on Florida soils, found that the retention of native and applied boron was greater at the higher pH levels (Table 1) but that the maximum plant uptake was at about pH 5.8 to 6.0 (see Table 2 for effect upon collards). Winsor stated that the retention of soil boron by excessively high reaction levels was at the expense of plant assimilation. Brioux and Jones (2) attribute the conversion of boron to the unavailable state in the over-limed soils to the formation of insoluble calcium borate, while Bobko et al (1), suggest that over-liming stimulates microbiological activity which depletes the soil solution of available boron. These theories, however, have not been widely accepted.

TABLE 2.—Influence of Reaction Levels in Lakeland Fine Sand Upon Boron Uptake by Collards, as Determined by Extraction from Foliage and by Ashing.

(As micrograms of boron from 5 sq. cm. of foliage)

Pounds per Acre		Soil pH	Foliage Boron	
Borax	Reaction Supplement		By Extraction	By Ashing
10	Sulfur 500	4.34	0.31	0.84
10	None	5.44	0.44	0 92
10	Lime 500	5.78	0.42	0.96
10	Lime 1500	5.99	0.51	1.16
10	Lime 4500	6.66	0.36	0.99

Zinc, Copper and Manganese

Zinc, copper and manganese are affected by pH in much the same way as boron, in that raising the pH decreases their availability.

Peech (12) added copper and zinc at the rate of 100 pounds per acre to samples of Lakeland (Norfolk) fine sand, and after adjusting the pH with sulfur and lime, brought them to 50% moisture content, left them 48 hours and extracted the available copper and zinc. His results, shown in Figure 3, indicate that the extractable copper and zinc decrease rapidly with an increase in pH and this decrease is much greater with copper.

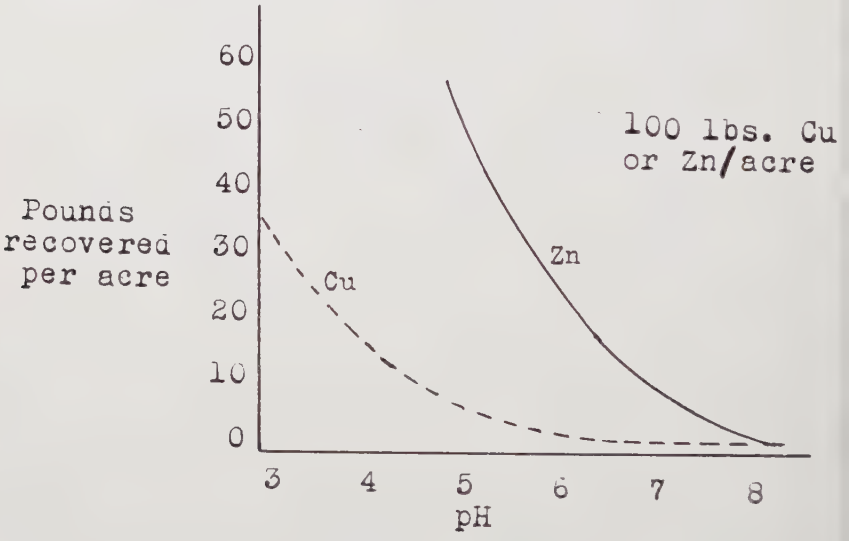

Figure 3.—Effect of pH on recovery of Zn and Cu from Lakeland (Norfolk) fine sand. Peech (12).

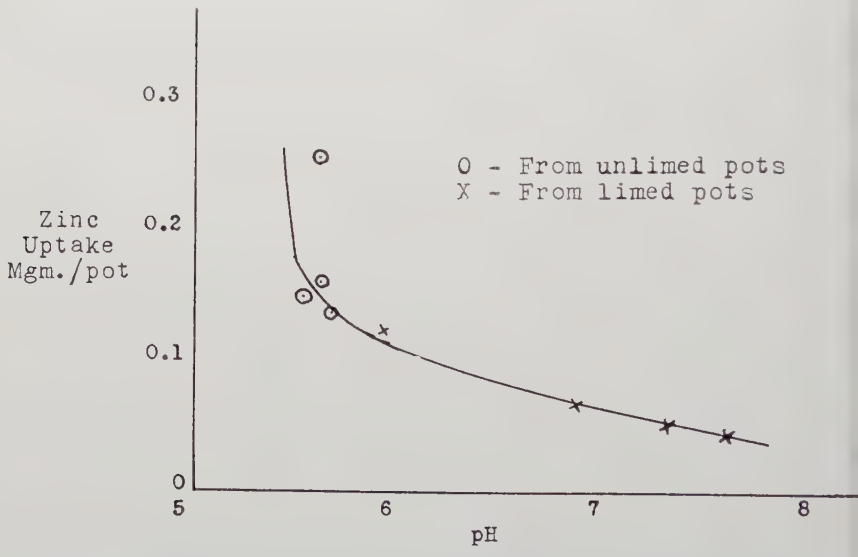

Figure 4.—Effect of pH on uptake of zinc by Camellia oats grown on Lakeland (Norfolk) fine sand. Wu (22).

Steckel (16) growing soybeans found that manganese deficient soils had a pH of 6.5 or greater. Wu (22) found that the uptake of zinc by oats was much less at higher pH values. Her results are shown in Figure 4.

It also has been found that liming soils of low pH value will counteract toxicity of these elements. This seems logical since liming would cause the quantity in excess to become unavailable. Similarly, liming border line soils would probably cause deficiencies.

For better preservation of copper, zinc and manganese in acid soils moderate liming is beneficial. Leaching becomes less at the expense of availability and it is a matter of weighing these two factors under Florida conditions. If just enough lime is added the decrease in availability might not be serious since the quantities of these elements required by plants are small; but if no lime is added to some of the more acid soils the losses due to leaching could result in severe deficiencies.

CONCLUSION

Some of the effects of lime on the availability of nutrient elements have been reviewed for nitrogen, phosphorus, potassium, molybdenum, boron, zinc, copper and manganese.

It can be said with certain reservations which include disease control and special crops, that Florida soils below pH 5.5 should be limed if more efficient utilization of applied fertilizer is desired. Similarly, under Florida conditions pH values above 6.5 should be avoided because of the reduced availability of many of the minor elements, for example, manganese, zinc, copper and boron. pH values above 6.5 have frequently resulted in deficiency of these elements and is known as overliming injury.

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THE USE OF LIMING MATERIALS ON ROW CROPS AND PASTURES

W. G. Blue *

There are essentially three reasons for applying liming materials to Florida soils. They are: (a) to change the soil reaction (pH), (b) to supply the essential plant nutrients calcium and magnesium, and (c) to reduce the loss of nutrients by leaching. These are not necessarily listed in order of importance since this is not always the same but depends on the combination of soil and crop in question.

The soil acidity tolerance of plants used for row crops and pastures is quite variable but most of them grow better at a pH range above 5.5. Most legumes are particularly sensitive although there is some question as to whether their lack of tolerance for acidity is due to the short supply of calcium associated with acid soils or to injury to their symbiotic bacteria. Since many Florida soils are too acid for optimum growth of most economic plants, liming materials must be used to reduce their acidity. The amount of lime which should be applied to obtain the desired change in soil reaction is not a constant factor but is dependent on the base exchange capacity and the degree of saturation of the soil colloids with bases. Table 1 shows the amounts of high grade calcic limestone necessary to raise the pH approximately 1.0 unit for soil areas with different exchange capacities resulting primarily from different organic matter levels (19).

TABLE 1.—The Maximum Amount of Ground Limestone Which Should Be Applied at One Time to Obtain 1.0 Unit Change in pH. Volk (19).

Soil Group	Pounds per Acre of Agricultural Limestone to Raise pH 1.0 Unit
Scrub land sands and white sands in general	500
High pine land fine sands and light gray flatwoods sands	1000
High pine land loamy fine sands and medium gray flatwoods sands	1500
High pine land sandy loams and dark gray flatwoods sands and sandy loams	2000
Clay loams, clays and black mineral soils, depending upon texture and humus content	2000-6000
Peats and mucks	6000

Most of the soils used for production of row crops and pastures in Florida are sandy and slightly to strongly acid. These conditions are

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indicative of soils in which leaching is very active and the result is a deficiency of the essential basic elements calcium, magnesium and potassium. It is generally necessary when improving these soils to apply liming materials to prevent possible deficiencies of calcium and magnesium.

Volk and Bell (18) have shown that potassium, ammonia nitrogen, magnesium and calcium leach less severely from slightly acid soils than from highly acid soils. Neller et al. (14) have shown that larger percentages of applied phosphorus are retained by sandy soils when the acidity is reduced by liming. On the other hand, most of the essential minor elements become more insoluble and unavailable for plant use at soil reactions maintained near neutrality as compared to more acid conditions, particularly on the lighter sandy soils. Peech stated that the soil reaction should not be increased above pH 6.0 in order to avoid minor element deficiencies (15).

ROW CROPS

Experimental work with corn and cotton in North and West Florida has not shown consistent response from the application of either high calcic lime or dolomite. Small yield increases have been reported for corn and cotton in some instances at the North Florida Station (20, 21, 22). Investigations in other parts of the country have shown that lime applied to soils with pH values similar to those of North and West Florida has benefited these two crops. This response has been attributed primarily to the increased availability of essential elements other than calcium and magnesium and to the change in soil reaction to favor increased microbial activity. The accelerated decomposition of the large reserves of organic matter and the accompanying decomposition of primary minerals in the soil released both nitrogen and the inorganic elements, which in some cases resulted in phenomenal yield increases. The practice of using lime alone practically devastated the soils of some areas of the East and Midwest before it was realized that other soil amendments and good management practices in addition to lime are necessary to maintain soil fertility.

Lime has been indirectly beneficial to non-leguminous row crops through its favorable action on the preceding green manure crops. Sweet clover which is used in many areas as the major green manure crop responds well to lime on most soils, but lupine, which is the predominant green manure crop in Florida, does not respond consistently to applications of lime even on soils which are quite acid. The reason for this is not fully understood. However, the tolerance for acidity of the symbiotic bacteria associated with lupine is greater than that of most legumes (9). It has also been reported that lime may not only fail to benefit lupine but may be injurious (6). Lupine is highly beneficial as a green manure crop in row crop production but because of its peculiar nature lime does not usually enhance its value.

The requirement for calcium and magnesium by non-leguminous crops is usually less than that for most legumes and it is possible that sufficient amounts of these elements are supplied in the low analysis mixed fertilizers used in their fertilization. Superphosphate contains about 20 per cent calcium and in addition many companies use dolomite as the filler

for fertilizers which are to be used on acid soils. "Floats," a product of the phosphate industry, is another material used which contains calcium.

The selection of new experimental areas each year has been one shortcoming of research involving lime applications on Florida soils used for growing these crops. Yields have also been low, and in many cases droughty conditions, thin stand of the crop or a greater deficiency of the other major plant nutrients have probably precluded yield responses from liming materials. At present, soil management experiments involving the use of liberal quantities of nitrogen, phosphorus and potassium with green manure crops and the use of proper cultivation practices have resulted in as much as threefold increases in yields of corn. The increased demand for calcium and magnesium brought about by larger yields should better establish the extent of need for liming materials on these soils.

The nutrition of peanuts presents a more complex problem than that of most row crops. The need for calcium and magnesium by this leguminous plant is rather high, yet Killinger et al. (12) reported that peanut yields in Central and North Florida were not increased by the use of either high calcic limestone or dolomite. Davis (7) reported that for soils in southeastern Alabama lime increased the yields of peanuts if the soils contained less than 0.72 m.e. of calcium. The number of mature kernels was also increased. Other workers (5, 13) have reported results similar to these and have indicated that the exchange capacity must have a high degree of saturation with calcium for best yields.

PASTURES

The improvement of pastures in Florida has been of relatively recent occurrence and it has been possible to profit by earlier work in other areas. Since the lack of water may limit yields of pastures the initial tendency has been to establish improved pastures on areas having good moisture relationships. This condition is favorable for excellent response to lime and other soil amendments. Both the heavier soils of west Florida and the sandy flatwoods soils of peninsular Florida are being used extensively for improved pastures. The fertility of the soil of both these areas in the virgin state was relatively low. The pH of the soils in the flatwoods areas is in general lower than that of the soils in west Florida. The range in pH for virgin flatwoods soils is about 4.0 to 5.0 while the pH values for soils in north central and west Florida ranges from about pH 5.0 to 6.0.

Contrary to the results obtained with the row crops, pasture plants, both leguminous and non-leguminous, have responded favorably to either high calcic limestone or dolomite in Florida. This is also true for most areas of the United States outside of the alkali areas of the west and southwest.

Blaser, in 1938 (1), showed that adapted strains of clover could be successfully grown when adequate quantities of lime and fertilizer were applied to the soil. Ground high calcic limestone at rates of 2000 to 4000 pounds per acre gave good results, and good clover growth was obtained with soil acidity varying from pH 4.9 to 6.0 and above. Both high calcic limestone and dolomite gave good results. In other work Blaser et al. (2) used a treatment of 2000 pounds of high calcic limestone, 600 pounds of superphosphate and 100 pounds of muriate of potash

per acre for mixed plantings of California bur and White clover on Leon fine sand pH 4.9 and Plummer fine sand pH 5.3. The substitution of dolomite for the high calcic limestone resulted in significantly lower yields on Leon fine sand, while yields were about equal on the Plummer fine sand. Yields on both soils were lower where the amount of lime used was decreased. There was also a differential growth of the two clovers. California bur, a Medicago species, made up a progressively smaller percentage of the number of plants as the lime was reduced. Also a reduction in the amount of high calcic lime applied, or the substitution of dolomite, decreased the calcium content of both clovers. The Trifolium clovers were well nodulated in all cases but the number of nodules was reduced as the amount of lime was reduced. The number of nodules on the Medicago-Melilotus clovers was less than on the Trifolium clovers with the standard treatment and nodulation was practically eliminated where no lime was added.

The need for selective liming of different clover combinations was previously emphasized by Stokes et al. (17). On an acid flatwoods soil the Medicago and Melilotus clovers gave greater response with high calcic limestone than with dolomite, while the Trifolium clovers responded equally well to either lime source. It is known that the former two genera of clovers favor higher pH values than the latter, either because of a high calcium requirement or the effect of the calcium on soil acidity and their symbiotic nitrogen fixing bacteria. Since the rate of solubility of dolomite with the same fineness of grinding is only about 50 percent as rapid as for high calcic limestone, the soil reaction would change more quickly with high calcic limestone and greater response would be obtained with the Medicago and Melilotus clovers from it than from dolomite, particularly the first year. Hodges (11), at the Florida Range Cattle Station, reported that most flatwoods soils require about two tons of lime per acre for clovers and that either high calcic lime or dolomite may be used.

Gammon et al. (10) in recent work at the West Florida Station on Carnegie and Tifton fine sandy loams have demonstrated clearly the need for lime on the heavier soils of West Florida. These data are shown in Table 2. The indicator pasture plants were White clover and Dallisgrass. Dolomite was used because it was readily available in that area but there was no readily apparent advantage or disadvantage from its use over high calcic limestone. One-ton per acre of ground high grade dolomite gave the largest yield increase per unit applied. Small yield increases resulted from rates of dolomite up to four tons per acre. Since the amounts of other nutrients added are now known to be only moderately high it was suggested that a two-ton rate might be more desirable.

The response of clovers to liming materials is probably due both to the increased calcium supply and to the increase pH of the soil. The symbiotic nitrogen fixing organisms associated with most of the clovers do not function efficiently at pH values much below 5.0. The optimum pH for some of them is above 6.0.

In 1938 it was reported that response with pasture grasses was obtained with mixed fertilizer on limed plots but not on unlimed plots (16). The pH of the soils varied from 5.64 to 6.02 on unlimed plots and from 5.89 to 6.32 on the limed plots. Six hundred pounds of $Ca(OH)_2$ per acre was used as the liming material. The favorable effect of the lim

could have been the result of either the correction of a calcium deficiency or a greater retention of other essential nutrients rather than to the reduction of acidity as such. Blaser and Stokes (3) reported that the omission of lime from a fertility program for pure stands of carpet grass resulted in retarded growth and plants with a lower calcium content. Yield responses from grasses seem to result to some extent from the calcium applied and certainly the calcium content of the forage plants is increased. However, much greater response results indirectly through the stimulation of clover growth and nitrogen fixation and the subsequent release of this nitrogen and inorganic elements for utilization by the grass plants after the clover has become dormant. Thus, in cases of grass-legume combinations which are being recommended for all areas with suitable moisture relationships, responses from liming materials are very high for both groups of plants (4, 10).

TABLE 2.—Effect of Lime on First-Year Yields of Lousiana White Clover-Dallis Grass Pasture Plots at West Florida Experiment Station. Gammon (10).

Dolomite	Soil	Fertilizer		Yields Air-Dry Herbage in Lbs. per Acre				
Lbs./Acre	pH	Lbs./Acre	Formula	4-1-49	5-16-49	8-11-49	10-10-49	Total
0	5.33	600	0-15-10	93	272	1523	428	2316
2000	5.88	600	0-15-10	423	750	2232	598	4003
4000	6 23	600	0-15-10	456	925	2685	676	4742
8000	6.51	600	0-15-10	410	951	2900	698	4959

Yields first year after application of dolomite.
Yields from first two cuttings represent white clover, and from last two Dallis grass.

Where ammonium forms of nitrogen are used for grass fertilization on highly acid soils, response from lime is also obtained through the decrease in soil acidity which creates more favorable conditions for growth and activity of the nitrifying organisms and results in a greater supply of nitrate nitrogen for grass nutrition. This is particularly true on some of the flatwoods soils such as the Leon fine sand which frequently has pH values below 4.5.

Experimental evidence has not shown dolomite to be of any value over calcic limestone for pastures. However, liming materials of some type must be used for satisfactory yields from pasture areas along with additions of the major elements and in some cases the minor elements. Dolomite usually gives results nearly comparable with high calcic limestone, and principles of soils and plant nutrition would indicate that fully as good results would be obtained if the dolomite were applied sufficiently in advance of seeding to allow for some decomposition. Dolomite has not increased forage yields over high calcic lime but the magnesium content of the forage is increased. The lack of yield response is somewhat confusing since most Florida soils are relatively low in magnesium. Forbes (8) reported that the bulk of magnesium in the flatwoods soils is present in the soil organic matter. The most reasonable explanation for lack of response is that areas chosen for pasture improvement are

comparatively high in organic matter and this supply of magnesium is supplemented with magnesium added in the high calcic agricultural limestone or in the filler material of mixed fertilizers.

The problem of maintaining soil fertility becomes increasingly difficult when vegetative material is removed from the soil by clipping or by intensive grazing. As more is learned about methods of curing hay under Florida conditions, greater quantities of forages may be removed from the soil to meet the demand for supplemental feed. Accompanying this will be a greater removal of plant nutrients, and it is likely that this factor, combined with continued use of the land, will create a need for dolomite and possibly minor elements.

SUMMARY

The field crops grown principally in north and west Florida do not respond consistently to either high calcic limestone or dolomite.

Pasture plants, both legumes and non-legumes, respond well to either high calcic limestone or dolomite on most mineral soils in the state but from the standpoint of yield increases there seems to be no benefit from dolomite over high calcic limestone. Pasture grasses planted in pure stands usually respond much less to lime than do pure stands of legumes, but in mixed plantings the grasses respond very favorably because of larger quantities of nitrogen fixed by the legumes and the release of some of this nitrogen for utilization by the grass when the legumes become dormant or die.

Even though some crops do not show a direct yield response to lime applications it is generally recommended for mineral soils that the entire farm area be limed to give a pH of about 5.5 to 6.0. This soil reaction will favor pasture plants and should improve row crops since more nitrogen will generally be fixed by legumes which respond to lime. The active organic matter will also be maintained at a higher level and the amounts of essential nutrients lost by leaching will be appreciably reduced.

While liming materials are extremely beneficial if properly utilized, there is some danger of overliming sandy soils of low buffer capacity if caution is not observed. Overliming can make minor elements unavailable and the productivity of the soil may be seriously impaired. It should be remembered that it is much easier to increase the pH to the proper level than to reduce it, in case it is too high.

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THE LIME REQUIREMENTS OF VEGETABLE CROPS ON THE SANDY SOILS OF THE LOWER EAST COAST OF FLORIDA

W. T. Forsee, Jr., N. C. Hayslip, W. A. Hills and Emil A. Wolf *

The discussion of lime requirements of any crop on the sandy soils of the Florida lower east coast involves a consideration of pH and calcium and magnesium needs. Methods of pH determination have been reviewed in some detail by Carrigan (2) and Volk (5). The effect of pH on the availability of ions in light sandy soils has been investigated and reported by Peech (4). The significance of pH as it relates to lime requirement, movement of surface applications of liming materials, base saturation, retention of potassium and ammonia, and solubility of phosphates also has been investigated and reported by Volk (5).

Liming experiments with vegetable crops have been conducted by the authors on the sandy soils of St. Lucie, Martin and Palm Beach Counties. Results of one experiment have been reported (3). This discussion is a review of the work that has been done to date by investigators at the Everglades Experiment Station on sources and application rates of liming materials used with vegetable crops on the mineral soils of the lower east coast of Florida.

The results of the liming phases of an experiment conducted during the spring of 1947 on Immokalee fine sand in St. Lucie County with tomatoes are recorded in Table 1. This soil had not been limed and the average analyses with respect to pH, Ca and Mg are represented by those reported for the check treatment, Table 1. The basic slag, dolomite and hydrated lime were broadcast at the rates of 2000, 2000 and 1000 pounds per acre, respectively, about three months prior to collection of the soil samples and about five months prior to collection of the tissue samples, the average analyses of which are recorded in Table 1. The analyses of both soil and tissue samples correlate very closely with each other and the various treatments. The total yields of tomatoes were increased significantly by all of the liming treatments. Random samples of mature green tomatoes which appeared to be externally sound were collected during the third picking. Six fruit from each plot were cut in half, examined and scored for a condition that may be described as an internal browning and hardening of small areas within the outer and radial walls of the fruit having the appearance of granules of brown, cork-like material. These scores, also recorded in Table 1, indicate that liming had a significant effect on the reduction of this condition. Although not statistically significant it may be of some practical significance that basic slag, of all the liming materials used, gave the highest yields and lowest incidence of internal necrotic tissue.

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TABLE 1.—Relation of Liming Treatment to Soil and Tissue Analyses and to Yield and Quality of Tomatoes on Immakalee Fine Sand in St. Lucie County.*

Treatment §	Soil Analyses **			Tissue Analyses† Oven-Dry Basis (%)		Tomatoes	
	pH	Ca Lbs/A	Mg Lbs/A	Ca	Mg	Total Yield, Field Crates/A	Score for Internal Necrotic Tissue ‡
Check	4.75	169	10	0.59	0.33	151	43
Basic Slag	6.13	495	35	0.75	0.42	273	10
Hydrated Lime	6.56	497	18	0.73	0.44	263	15
Dolomite	6.31	413	113	0.64	0.57	235	20
L.S.D. (19:1)				0.11	0.06	48	23

* Average of four plots.

** Glass electrode method for pH, 0.5 *N* acetic acid soluble Ca and Mg.

† Filtrates from extraction of fresh stem tissue in a Waring Blendor with 0.5 *N* acetic acid.

‡ Internal browning condition of six externally sound mature green fruit from each plot scored on the basis of none = 0, slight = 1, medium = 2 and severe = 3.

§ Basic slag and dolomite applied at rate of 2000 pounds and hydrated lime at 1000 pounds per acre.

A similar type experiment was conducted with tomatoes and squash on a Sunniland fine sand in Martin County during the 1947-48 season. The results of that portion of the experiment dealing with the effect of liming materials on tomatoes are recorded in Table 2. The dolomite and slag were broadcast at rates of 1000 pounds per acre in September and again in February prior to collection of soil samples in March and tissue samples in May. Here again good correlation was obtained between soil tests, tissue tests and treatments. Tomatoes showed a significant yield response to basic slag treatments. Since the soil reaction before liming was quite satisfactory, pH 5.76, it is not at all surprising that the yield responses were small. After the first two pickings it was noted that fruit from some of the treatments had a tendency to become soft after harvesting and to break down severely during shipping. In order to check the relationship of this characteristic to treatment, one box of fruit was saved from each plot during the fourth picking. After washing and sorting in the field each lot of fruit was run over the belt at a packing house and waxed. The boxed fruit samples were placed in a refrigerator car for six days, removed and allowed to stand at room temperature for three more days. Ten days after picking the tomatoes were then examined for spoilage and internal quality. There were no differences in spoilage with respect to treatment as determined by an examination of external condition. Twenty-five ripe and externally sound fruit from each plot were cut in half and examined for internal breakdown consisting of soft, light-colored or yellow spots in the walls between or around the seed sections. Many of the fruit showing such symptoms had a strong odor and taste of over-ripe tomatoes. The results of this examination with respect to liming treatment are recorded in Table 2. Highly significant differences were obtained. Fruit from the basic slag plots was statistically more sound than that from any other treatment.

However, the dolomite treatment produced fruit statistically more sound than the check treatment.

TABLE 2.—Relation of Liming Treatments to Soil and Tissue Analyses and to Yields and Quality of Tomatoes on Sunniland Fine Sand in Martin County.*

Treatment §	Soil Analyses **			Tissue Analyses † Oven-Dry Basis (%)		Tomatoes	
	pH	Ca Lbs/A	Mg Lbs/A	Ca	Mg	Total Yield, Field Crates/A	Internal ‡ Softening (%)
Check	5.76	360	23	0.81	0.29	556	46
Dolomite	6.67	638	95	0 92	0.44	588	34
Basic Slag	7.04	721	41	1.00	0.31	627	23
L.S.D. (19:1)	.....	.....	.....	.....	.....	45	11

* Average of five plots.

** Glass electrode method for pH, 0.5 *N* acetic acid soluble Ca and Mg.

† Filtrates from extraction of fresh stem tissue in a Waring Blendor with 0.5 *N* acetic acid.

‡ Percent of externally sound fruit showing some form of internal breakdown after ripening. Estimates made by J. C. Hoffman, Associate Horticulturist, Everglades Experiment Station, Belle Glade, Florida.

§ Dolomite and slag applied broadcast at 2000 pounds per acre in two equal applications.

A second crop of tomatoes was grown on the Martin County plots during the fall of 1948. Bacterial wilt depleted the stand to such an extent that there was no way to measure yield variations with respect to treatment. A random sample of 50 tomatoes was collected from each plot at the time of the fourth harvest. Average weight per fruit was larger and the fruit were firmer from the limed plots than from the unlimed plots but the differences were not statistically significant. Two other experiments with tomatoes on Immokalee fine sand in eastern Palm Beach County failed to show any significant differences with respect to yields and quality among eight different liming treatments.

In both experiments represented by the data in Tables 1 and 2 some foliage symptoms of magnesium deficiency were noted on part of the check plots. The symptoms were more severe on the plots represented by Table 1. A careful study of the soil and stem tissue analysis data in Tables 1 and 2 indicates that no magnesium deficiency was diagnosed where the soil test for Mg was 35 pounds per acre or above and where the stem tissue showed 0.31 percent or more of this element. In order to insure, with some margin of safety, absence of magnesium deficiency on tomatoes these data indicate that the soil should test above 40 pounds per acre and the extracted fresh stem tissue about 0.40 percent or higher on the oven-dry basis.

Soil heterogeneity caused by small patches of marl and soft limerock near the surface in some plots on the experimental area in Martin County classified as Sunniland fine sand afforded an opportunity to study the response of tomatoes and yellow crookneck squash to soil pH, whether caused by naturally occurring lime or applied lime from any source. A scatter diagram of squash yields is shown in Figure 1 and of tomatoes

FIGURE 1,—SCATTER DIAGRAM OF SQUASH YIELDS WITH SOIL pH⊛

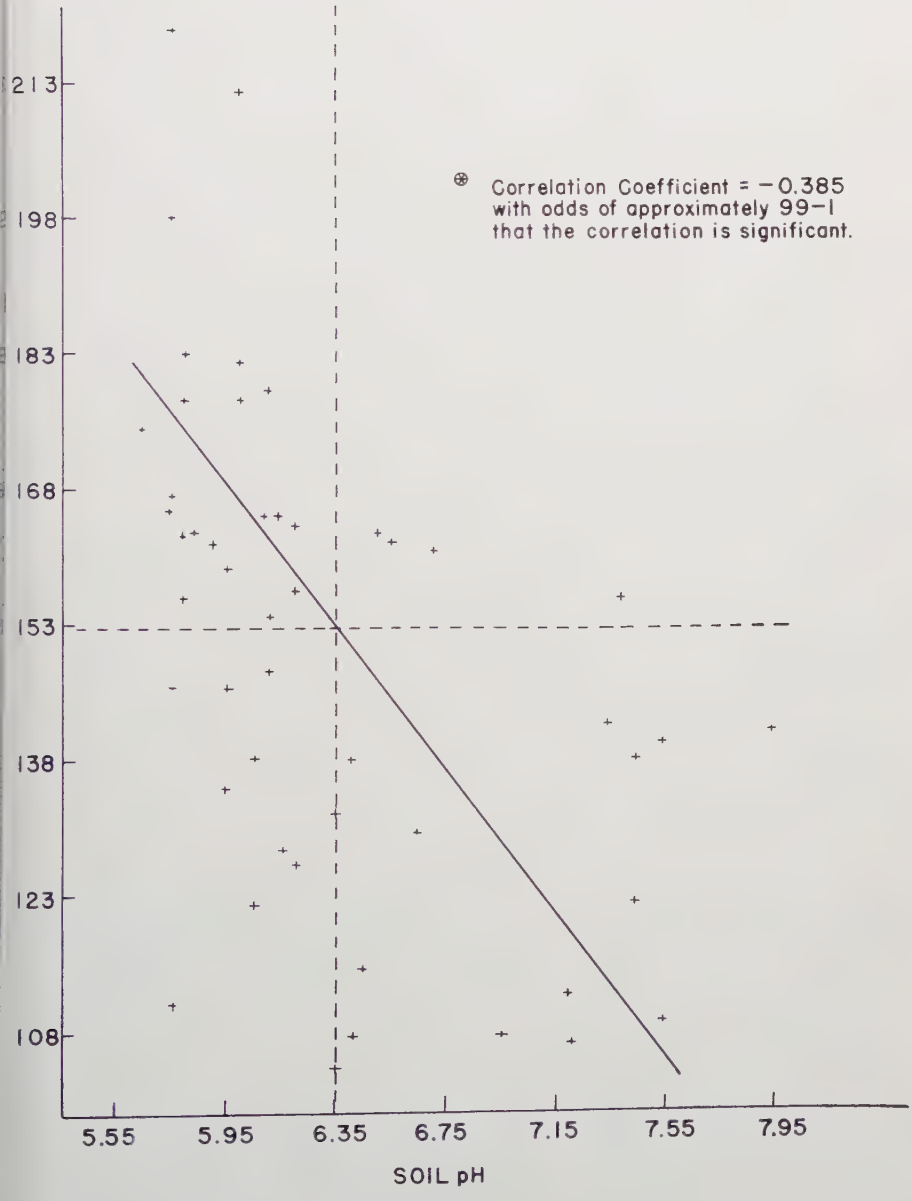
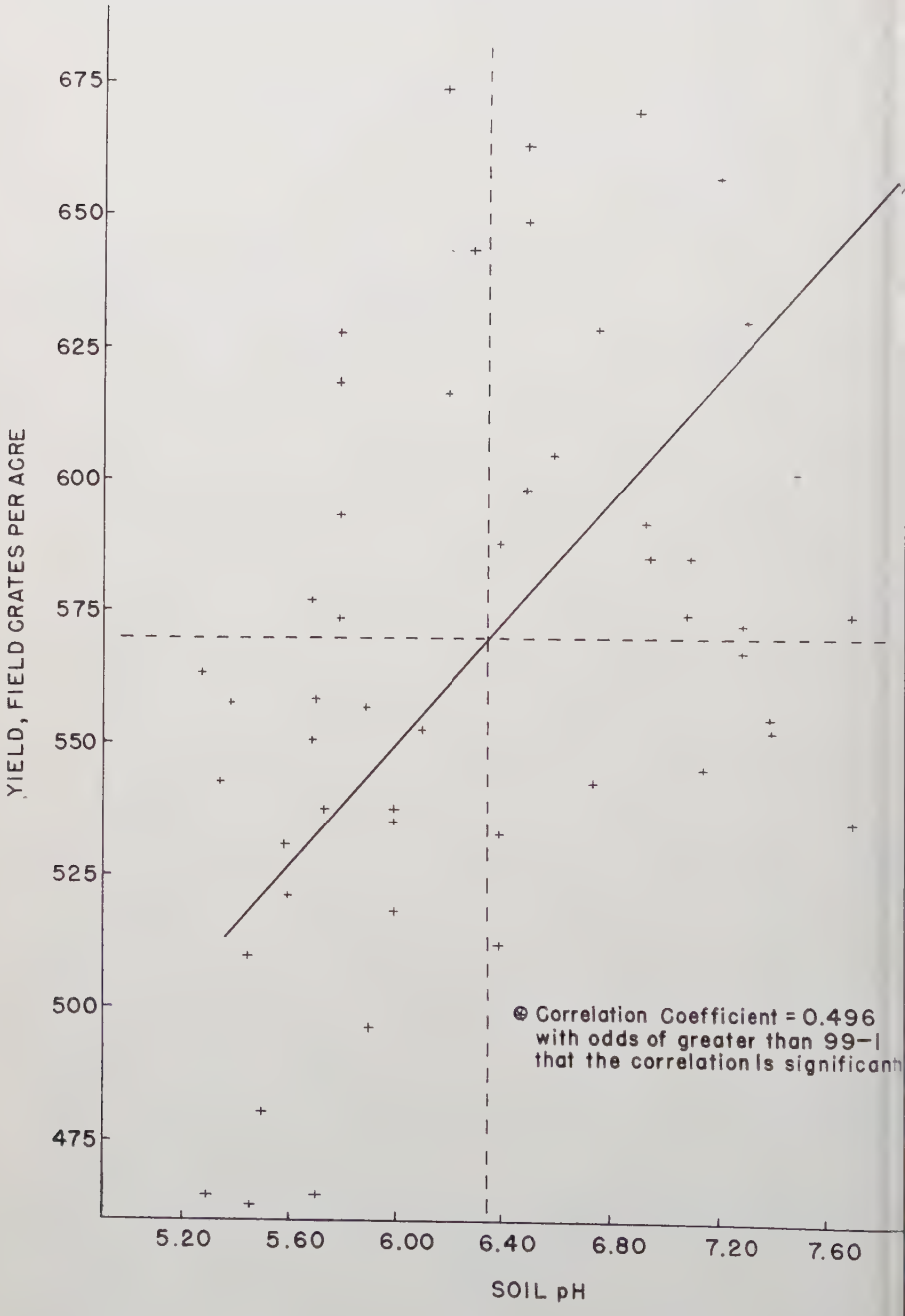


FIGURE 2.- SCATTER DIAGRAM OF TOMATO YIELDS WITH SOIL pH ⊛



in Figure 2. The yield trend for squash was downward as the pH increased from 5.60 to 7.90 while the yield trend for tomatoes was upward as the pH increased from 5.30 to 7.60. Although not conclusive, the data indicate trends that should be considered when contemplating a liming program for either of these crops. In contrast to these data Beckenbach (1) in 1946 obtained reduced yields of tomatoes with high lime treatments on Bradenton fine sandy loam while in 1948 there was no yield response in the same crop with pH increases from 4.8 to 6.8.

Treatments consisting of several lime sources and gypsum applied at rates of 2000 pounds per acre were made to a set of plots established in 1949 on Immokalee fine sand in eastern Palm Beach County. These plots were planted to several different vegetable crops during a three year period. Some of the data are recorded in Table 3. Although soil samples were collected during each crop, only the average analyses for those obtained during the spring of 1950 are recorded in the Table. The effects of the liming treatments on the soil pH, and on the Ca and Mg contents are obvious and somewhat according to expectations. The large amount of magnesium in dolomite and the somewhat smaller amounts in the slags are reflected in the results of the soil tests. Although 2 percent MgO had been included in the fertilizer for the gypsum treatments for almost two years of cropping, it did not show in the test. Evidently the unused amounts had been lost through leaching. Most of the calcium in the gypsum was not removed by the 0.5 *N* acetic acid used in the soil tests to extract the bases. Some of the average vegetable yields for 1949, 1950 and 1951 are recorded in Table 3. The only crops that showed statistically significant yield increases to applications of any of the lime sources were snap beans and sweet potatoes. Beckenbach (1) reported higher bean yields in 1944 with the use of dolomite applied at the rate of 1500 pounds per acre on Bradenton fine sandy loam. Squash, Table 3, showed a tendency to increased yields but the differences were not statistically significant. This is a reversal of the trend indicated by the scatter diagram of another experiment represented in Figure 1. However, the latter crop was grown in a pH range of 5.60 to 7.90 while the range in the experiment of Table 3 was 4.68 to 5.90. Lima beans showed a tendency toward decreased yields due to liming. Gypsum with soluble magnesia gave no yield response with any of the crops. In fact, all yields with but one exception were below the check and this exception, snap beans in 1950, was equal to the check in yield.

The danger of overliming, which is a distinct possibility on light soils when intensively cropped, is a question of considerable importance and one which may involve extensive damage to the soil especially where soluble hydrated forms are used. During the 1950-51 season a series of experiments was conducted on a Sunniland fine sand in Martin County. The area had been previously limed two times within a year with basic slag and a high calcic form to an average pH of 6.36. Dolomite, high calcic limestone, basic slag and hydrated lime were applied at rates shown in Table 4. Sweet corn and cucumbers were planted, the sweet corn as an early winter crop and the cucumbers in the spring. The average analyses of soil samples collected from the plots about six months after the liming materials were applied are recorded in Table 4. The pH

TABLE 3.—Soil Analyses and Vegetable Yields from Lime Source Plots on Immokalee Fine Sand in Eastern Palm Beach County.

Treatment *	Soil Analyses †			Yield,** 1949	Yields, Lbs/Plot, 1950				Yields, Lbs/Plot, 1951	
	pH	Ca Lbs/A	Mg Lbs/A	Tomatoes Lbs/Plot	Snap Beans **	Tomatoes	Yellow Squash	Sweet Potatoes **	Snap Beans	Lima Beans
Check	4.68	379	36	97	34	139	78	80	19	86
Dolomite	5.63	574	156	113	44	148	104	114	37	106
Basic Slag, Tennessee Ground Open Hearth	5.41	543	68	85	41	125	97	76	26	83
Fairfield Slag, Ground Open Hearth	5.49	619	93	112	47	134	91	96	33	87
Blast Furnace Slag, Water Granulated	5.53	626	133	92	46	128	102	113	23	74
Gypsum + Sol. MgO	4.78	414	33	80	34	133	72	49	15	56
Dolomite + Rock Phosphate	5.90	738	179	103	42	151	79	69	25	79
Dolomite without Minor Elements	5 52	534	161	77	41	148	105	99	26	80
L.S.D. (19:1)	.....	.....	.....	N.S.D.	4	N.S D.	N.S.D.	22	10	N.S.D.
L.S.D. (99:1)	.....	.....	.....	N S.D.	6	N.S.D.	N.S.D.	29	14	N.S.D.

* Liming materials and gypsum had been applied at the rate of 2000 pounds per acre in two applications.
** Average for two varieties whose yield trends were similar with respect to treatment.
† Averages of analyses made on samples collected in 1950. Glass electrode method for pH; 0 5 *N* acetic acid soluble Ca and Mg.

values had not increased above 6.91 on any of the treatments. The highest pH value from dolomite applied at 4000 pounds per acre was only 6.65. This is in agreement with experiments of Beckenbach (1) who reported in 1949 a maximum pH of 6.9 which dropped after six months to 6.5 after the last of a series of seven yearly applications of 1500 pounds per acre of dolomite had been made on the Bradenton fine sandy loam. The analyses for Ca and Mg clearly show the relative amounts of these elements present in the soil after treatment. Sweet corn showed no yield differences or even trends except that there was slight tendency toward reduced yields with hydrated lime and with the highest dolomite application. Although not significant, the length of unfilled tip on the ears of sweet corn appeared to be slightly reduced by all of the liming treatments.

Just prior to the first harvest of cucumbers the general appearance as to growth, color and overall vigor of the vines was scored by a commercial cucumber grower. The average scores and yields are recorded in Table 4. Although not significant, the vine scores on general appearance tended to improve with all treatments except hydrated lime which was the same as the check. The basic slag treatment yielded higher than the check while all other yields were equal to or just slightly less than the check. It may be noted that the basic slag treatment also gave the highest appearance score. On an adjacent area cucumbers responded outstandingly to regular applications of a nutritional spray containing "Nu-M", a neutral manganese sulfate. The apparent response to basic slag may have been due to the manganese contained in this source of liming material.

Three unreplicated liming tests have been conducted on soils of the Immokalee and Sunniland series with fourteen different vegetable crops. Generally speaking, all except sweet corn showed yield increases up to a pH of approximately 5.50 to 5.70, and sweet corn showed an improvement in quality and earliness of maturity. Beyond this point the yield responses have been quite variable, some being positive and some negative. Lima beans and squash were most consistent in their yield decreases past a pH of approximately 5.50 to 5.80. Pepper, eggplant, tomatoes and snap beans usually responded to lime. Others were rather erratic in their responses. Beckenbach (1) reported in 1949 that "Bradenton series soils of pH 5.1 to 6.8 range will not respond to liming, either in returns from a cash crop or in growth of leguminous or other summer cover."

These and other experiments carried out on the sandy soils of Florida indicate that it would be best for general vegetable production to adopt a liming program that would hold the pH value within a range of 5.60 to 6.00. This pH range seems to be safe for most vegetable crops and is fairly consistent with good soil conservation practices. Somewhat higher pH values may be maintained for certain vegetable crops with some possibility of increased yields and quality. Most of the so-called "insoluble" sources of lime are rapid enough in their action for general use and seem to be safe to use insofar as the dangers of over-liming are concerned. Where magnesium is limiting, as it is on most of the sandy soils of the Florida lower east coast, a magnesium bearing material is recommended at least for periodic applications. Because of the outstanding results in increased yields and improved quality obtained from open hearth slags, these materials are suggested for use in a well-balanced liming program.

TABLE 4. Relation of Sources and Application Rates of Certain Liming Materials to Soil Analyses and to the Production of Sweet Corn and Cucumbers on Sunniland Fine Sand in Martin County.*

Treatment **	Soil Analyses †			Sweet Corn		Cucumbers	
	pH	Ca Lbs/A	Mg Lbs/A	Yield of Marketable, Lbs/Plot	Average ‡ Length of Unfilled Tip, cm.	Score § of Vine Appearance	Total Yield Lbs/Plot
Check	6 36	870	88	31	3.2	3.9	98
Dolomite at 2000	6.59	1260	252	30	3.0	4.5	98
Dolomite at 4000	6.65	1560	368	28	2.9	4.7	92
High Calcic at 2000	6.91	1350	92	30	3.1	4.3	89
Basic Slag at 2000	6.85	1170	136	30	2.6	4.9	111
Hydrated Lime at 500	6.85	1010	86	27	2.7	3.9	95
Dolomite at 2000 + Colloidal Phos. at 4000	6 59	1190	204	31	3.2	4.2	93
L.S.D. (19:1)	0.27	240	43	N.S.D.	N.S.D.	N.S.D.	N S.D.
L.S.D. (99:1)	0.36	323	57	N.S.D.	N.S.D.	N S.D.	N.S.D.

* Average of five plots.
** All materials except hydrated lime applied broadcast.
† Glass electrode method for pH. Ca and Mg determined on flame photometer after extraction with 0.5 *N* acetic acid.
‡ Average of a 25 ear random sample from each plot.
§ Scored just prior to harvest by Mr. B. G. Leighton, a commercial grower, on the basis of 1 = very poor to 10 = very good.

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THE USE OF AGRICULTURAL LIMESTONE AND DOLOMITE IN FLORIDA CITRUS PRODUCTION

I. W. Wander *

The use of finely ground agricultural limestone or dolomite in the production of citrus is practiced by most grove owners or their caretakers. However, the reasons for the use of dolomite or lime is not always clearly understood even by those who realize the value of such materials. The limitations of their use on mineral-deficient. acid, sandy soils is often confused with their use on heavier, mineral-rich soils. The philosophy that if some is good, more ought to be better, with respect to the use of lime, backfired on many grove owners. Such misunderstanding has resulted in severe damage in the past and, indirectly, by association, is resulting in losses of production at present.

The bad effects from overliming citrus in Florida are well known and the minor element dificiencies resulting have been described and seen by many. Although the dangers of overliming should in no way be minimized, it is believed that many growers have thus been influenced to use little or no limestone or dolomite in their regular program. This attitude coupled with the practice of using straight nitrogen sources plus high analysis mixtures containing no dolomite filler is resulting in many groves becoming too acid for efficient production.

For this reason it is believed desirable to point out the advantages of using adequate amounts of basic materials when producing citrus on the acid, sandy soils of Florida. The use of the term lime or basic materials in this discussion refers to the use of either finely ground high calcium limestone or dolomite. For practical purposes it is felt that the two materials can be used interchangeably on equal basis for the maintenance of soil reaction. It is understood that at low soil pH values, some magnesium will become available from dolomite. However, when the soil reaction is maintained at from 5.5 to 6.0, relatively little magnesium is available to citrus from dolomite.

One of the best illustrations of the advantages of soil pH control under field conditions can be found in a block of mature grapefruit trees located at the Citrus Experiment Station. Duplicate plots (four in all) of 24 trees each have been maintained since November 1938 with the same fertilizer program, differing only with respect to soil reaction. Four varieties, Marsh, Duncan, Excelsior, and Walters, are present in each treatment and each treatment receives at present a total of 75 pounds of a 4-6-8-4-1-1 mixture per tree during the year. The fertilizer applications are split into three equal parts of 25 pounds each in the spring, summer and fall. Two of the four plots receive finely ground limestone in sufficient amount to keep the soil reaction between 5.5 and 6.0 pH, while two other plots receive no supplemental lime and thus show a reaction of from 4.0 to 4.5 pH.

Soil samples were taken once each month during the period from September 1949 to September 1950 and analyses made for pH, extractable

* Citrus Experiment Station, Lake Alfred.

calcium, magnesium, potassium, phosphorus, and manganese. Extractable refers to that portion of calcium (or other nutrient) dissolved from a definite weight of soil in a definite volume of extracting solution, in this case sodium acetate buffered at pH 4.8. Soil reaction determinations (pH) were made with a glass electrode on a 1 to 1 ratio of soil to water mixture of previously air dried soil.

The average pH and pounds per acre of extractable calcium, magnesium, potassium, phosphorus and manganese in the soil from controlled and uncontrolled plots during the period from September 1949 to and including September 1950 are given in Table 1. These results indicate the degree of difference in soil analysis which may be expected during a complete growing season. Although considerable fluctuations occur due to effects of fertilizer applications and rainfall, this average represents the level of nutrition which can be maintained over a period of time.

TABLE 1.—pH and Pounds per Acre Extractable Ca, Mg, K, P, Mn.

Treatment	Average of 13 Soil Samples Taken at Monthly Intervals—9/20/49 - 9/21/50					
	pH *	Ca	Mg **	K	P	Mn
Controlled	5.6	1123	28.3	64.7	64.7	23.5
Uncontrolled ..	4.3	231	22.1	57.7	41.4	10.7
Controlled plots have	19 times less acid	386% more Ca	28.0% more Mg	12.1% more K	56.3% more P	136% more Mn

* Arithmetical average.

** It should be noted that these analyses represent results obtained from soil where the pH has been controlled by using high calcium limestone. Although the availability of magnesium to citrus would be no greater, much higher magnesium values would be found where dolomite has been used. This is due to the solubility in the extracting solution of magnesium carbonate which has accumulated in soils from dolomite applications.

The soil reaction in the plots receiving no lime shows the presence of 19 times as much active acidity compared to the plots receiving lime. This is greater acidity than is found in virgin soils of the same type. Such a result is to be expected in view of the use of sulfur sprays and dusts and the acid forming residues from sulfate forms of fertilizer source materials. It is not often realized how much lime is required to react with sulfur. To completely react one pound of sulfur requires a little over three pounds of lime. Thus the potential acidity added in the regular spray and dust program, where between 200 to 300 pounds of sulfur per acre per year is used, would require 600 to 900 pounds of calcium carbonate per acre per year or its equivalent.

The amount of extractable calcium is 386 percent greater in the limed plots compared to the unlimed areas. Triple superphosphate is used in the limed plots whereas ordinary 20 percent superphosphate containing 50 percent calcium sulfate is used on the unlimed plots in order to make the addition of calcium more nearly equal to each plot. Evidently the addition of calcium sulfate on the unlimed plots is readily lost by leach-

ing. It is also evident that it is necessary to maintain a pH higher than 4.5 to accumulate calcium.

The quantity of extractable magnesium was found to be 28.0 percent greater in the plots receiving limestone over the period studied although the amount of soluble magnesium received by all plots was the same. Analysis of variance showed this increase to be significant. The extractable potassium was 12.1 percent greater which is not great enough to be significant but appears to be in favor of the pH controlled plots. The increases of both extractable manganese and phosphorus are highly significant being 136 and 56.3 percent respectively for the controlled plots as compared to the unlimed plots.

TABLE 2.—Total Pounds per Acre Ca, Mn, Cu, and Zn.

Treatment	Average of 12 Samples Taken from 8/26/48 to 8/15/49				
	Ca	P	Mn	Cu	Zn
Controlled	1340	507	228	166	59
Uncontrolled	246	344	30	141	4.8
Controlled plots have	445% more Ca	47 5% more P	660% more Mn	17.7% more Cu	1135% more Zn

A similar pattern is revealed when analyses are made for total calcium, phosphorus and manganese in these plots. The total amounts of calcium, phosphorus, manganese, copper and zinc in the soil during the period August 1948 to August 1949 is shown in Table 2. Analyses for total copper and zinc also show significantly greater amounts present in the pH controlled plots. It is interesting to note that much less difference is found in copper concentration between the two treatments than for any other element studied except extractable potassium. Evidently copper is closely related to the organic matter present in the treatments because the organic matter content of all plots is nearly equal.

TABLE 3.—Yield in Pounds per Tree.

Treatment		1948-49	1949-50	1950-51	3 Yr. Avg.
Controlled	5.6 pH	658	355	1048	687
Uncontrolled	4.3 pH	284	195	564	348

It would appear that, if soil analyses are of value in indicating nutrition levels available to citrus trees, production should be greater where the soil reaction has been controlled. This is substantiated by yield records for the past three years in these plots as shown in Table 3.

Yield records reveal a 97.5 percent increase in production during the past three years. This has evidently been due to a higher level of nutrition maintained through pH control as revealed by soil analysis.

As mentioned previously, fertilizer applications were equivalent on both treatments. It should be stressed, however, that a large number of soil samples spread over a long period of time (13 sample dates during one year) are required to show true differences thus eliminating fluctuations due to rainfall and fertilizer applications.

The conclusion from such studies would be that controlling the soil reaction on the acid sandy soils planted to citrus through the use of adequate but not excessive basic materials is of great importance in providing for increased utilization of applied fertilizers.

THE LIME REQUIREMENTS OF ORNAMENTALS

R. D. Dickey *

Experiments designed to give information on the lime and nutritional requirements of ornamental plants under Florida growing conditions are, so far, few in number. Considerable work has been done, however, with other commercially grown plants, for example, citrus, vegetables, tung trees and avocados, which show that these plants respond by better growth and yields to fertilizer applications. It is to be expected that the miscellaneous group of plants used as ornamentals would also respond to fertilizer applications. Many observations attest this fact. It follows, therefore, that any management practice which would maintain or improve the fertility level of a given soil would be advantageous to the plants growing therein.

The exchange capacity of a soil is a good index of its ability to absorb and retain a group of important plant food elements designated as "exchangeable bases". Several factors influence this ability, but for light sandy soils, particularly, two of the most important factors are pH and organic matter content. Some control can be exercised over both of these important factors because organic matter can be added and the acidity of acid soils can be reduced by the use of lime.

Work with citrus and vegetables indicates that on sandy soils a pH range of about 5.5 to 6.0 is best for the maximum retention and use of the exchangeable bases and that this is usually reflected in better growth and yields of these commercially grown plants. This being generally true for citrus and vegetables, it is likely that many ornamentals will respond similarly, that is, they will attain their best growth and appearance on soils that are not extremely acid in reaction. There seems little doubt that many ornamental plants growing on sandy, clay or muck soils that are very acid in reaction, would benefit from the application of lime either in the form of dolomite or agricultural lime. This point is of importance because much of our ornamental plantings are on acid sand soils.

Soil reaction plots were established at Gainesville, Florida, on light Arredondo soil in 1926. The pH reactions determined in 1940, which are representative of the pH levels throughout the experiment, are given in Table 1. In the initial applications, sulfur was applied to treatments 1 and 2 at the rates of 1000 and 500 pounds per acre, respectively; treatment 3, untreated check; treatments 4 to 6 were given applications of limestone at the rates of 1000, 2000 and 4000 pounds per acre, respectively. Smaller amounts of sulfur and limestone were applied in 1931, 1934 and 1937 to maintain pH at the desired level. Three commonly grown ornamental plants, severinia, *Ligustrum lucidum* and Rosedale arborvitae were planted in the soil reaction plots in June, 1938. The growth responses of these plants as measured by the average height of plants in the treatment is given in Table 1. The data suggest that these three species of ornamental plants, if grown on sandy soils having a pH of about 5.5 or lower, would benefit from the moderate addition of lime.

* Florida Agricultural Experiment Station, Gainesville, Florida.

TABLE 1.—Growth of Three Ornamental Plants in Soil Reaction Plots.

Treatment		Ornamental Plant (Height in Inches)*		
No.	pH	Severinia	*Ligustrum lucidum*	Rosedale arborvitae
1	4.48	12	15	11
2	4.66	15	16	13
3	5.44	26	29	22
4	6.07	30	41	25
5	6.59	33	39	23
6	7.34	28	40	24

* Planted June 30, 1938, measurements taken May 27, 1941.

Barnette and Mowry (1) reported on a controlled experiment with the Formosa variety of azalea which was started in 1931. A sandy soil with a relatively low content of organic matter and an original pH of 5.76 was placed in 4-gallon glazed pots and adjusted to give different degrees of acidity. They found that below pH of 5.00 the plants made a slow but healthy growth and the foliage was dark green. The plants grown between pH 5.00 and 6.00 were healthy and twig growth was lengthened which produced a larger but not spreading plant with dark green foliage. Between a pH range of 6.00 to slightly above 6.50 the growth was rapid with distinctly elongated stems between the whorls of branches which produced a somewhat open sprawling type of plant. Foliage was healthy and flowering normal. A distinctly unhealthy plant condition was observed at pH 7.00 and above evidenced by shortened growth with distinctly chlorotic leaves and sparse foliage. Experience with azaleas growing under field conditions indicates that when the reaction of sandy soils, particularly, goes above a pH of about 6.00 the incidence of iron deficiency, with its resulting unhealthy plant condition, is considerably increased.

Gammon and Wilmot (2) reported their experiment on soil acidity and camellia growth. By the use of a nutrient medium with artificial zeolites they were able to establish in 4-gallon jars, artificial media which had a theoretical pH range of 3.0 to 8.0. One plant each of four camellia varieties was established in each jar. A picture of the jars used in the experiment and the plants growing in them showed that all the plants in the pH 8.0 culture were dead and only one plant of four survived in the pH 7.0 jar and it had made poor growth. Those plants in the jars which had a theoretical pH range of from 6.0 to 3.0 appeared healthy. They state that it is not known whether the poor condition of the plants in the pH 7.0 and 8.0 jars was due to the high sodium content. Camellias have often been referred to as one of a group of so-called acid loving plants. Under field conditions, however, both healthy and unhealthy plants have been observed at a wide range of soil reaction. This seems to indicate that they are not as likely to develop physiological troubles incident to overliming as they have been given credit for and should not, as is frequently done, be listed along with azaleas as being especially intolerant of alkaline soils. It is possible that camellias would also benefit from the application of lime to very acid soils.

Ornamental plants are usually grown in locations that make cultivation and fertilization as practiced with tree or vegetable plants difficult if not impossible. Those individuals who plan on landscaping their own grounds may have the reaction of their soil determined. If their soil runs much more acid than a range of pH 5.5 to 6.0 it would probably be advisable to adjust the pH to this range by the addition of lime. This could be done for shrubs and trees by applying the lime to the area to be occupied by the root systems of the plants and working it into the ground before planting. It is much more difficult to adjust the pH of the soil area about established woody ornamental plants, because little if any cultivation can be used to incorporate the lime in the soil and Volk and Bell (4) have shown that the penetration of lime is very low.

The amount of lime to apply will vary depending upon several factors, some of the most important of which are pH of the soil, organic matter and clay content, base exchange capacity, the soil reaction to be attained and the liming material used. The information that is needed to determine the amount of lime to apply to adjust the soil reaction to the desired pH is given by Volk (3) in Press Bulletin 606.

If there were no other consideration than the addition of lime, the best material to use for this purpose would be a high grade agricultural lime. However, the acid sandy soils of Florida usually run low in magnesium so there is the ever present possibility that magnesium may be at or near the deficiency level for some ornamental plants. Because of the possible need for magnesium, dolomite should be given preference for ornamental plants because it will satisfactorily adust the soil reaction and at the same time supply magnesium if that element be needed.

The ill effects of overliming light sandy soils in Florida have been stressed in recent years. With ornamental plants this trouble is usually present naturally on the alkaline sands of the coastal areas and the marl soils of extreme southern Florida. A condition of overliming is often produced in very localized areas as the soil immediately adjacent to the walls and foundations of brick and stucco buildings often become alkaline in reaction. Mortar may be mixed with the soil in the foundation planting area about buildings as a result of construction operations which produces localized overlimed areas. These possibilities should be kept in mind by those attempting soil reaction adjustments on acid soils in residential areas.

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PANEL DISCUSSION: SOIL AND WATER CONSERVATION OPERATION AND PLANNING IN THE EVERGLADES AREA AS INFLUENCING SOIL SUBSIDENCE AND ULTIMATE LAND USE CHANGE*

Leader: W. Turner Wallis, Chief Engineer, Central and Southern Florida Flood Control District, West Palm Beach

Co-Leaders: Leo L. Burnet, Chief, Engineering Division, Corps of Engineers, U. S. Army, Jacksonville and Horace A. Bestor, Consulting Engineer, Clewiston

Secretary: R. V. Allison, Belle Glade

Dr. I. W. Wander, Vice President of the Society, acting in the absence of President Carrigan, called the meeting to order and turned the chair over to R. V. Allison, Secretary of the Society and of the Panel.

R. V. Allison:

The unusually good attendance this evening, including, as it does, so many growers and others directly interested in the life and welfare of our Everglades soils, is a better evidence than any other of the importance of the subject we are about to discuss. I dare say there are few present in this room who do not know of the perishability, under drainage and use, of the ogranic soils that make up the broad expanse of the Florida Everglades. In other words, these soils are like the cake which we cannot eat and keep. In this instance we cannot farm these soils and keep them for this purpose thru that indefinite and endurable period which we like to associate with well-managed lands.

Since the plan of the discussion is quite fully outlined in the sheets that have been passed out and will doubtless largely hinge on an analysis of this report[1] (holds up copy) on the "Subsidence of Peat Soils in the Everglades Region of Florida" that recently has been compiled from existing information by Messrs. J. C. Stephens and Lamar Johnson, I should like without further ado to turn the meeting over to our very capable discussion leader, Mr. W. Turner Wallis. Turner knows the physical and financial problems of the Everglades, including the many complicated angles of tax structures and zoning, better than any other man in South Florida. We are fortunate, indeed, that he is able to be with us and lead the discussion this evening.

W. Turner Wallis:

Thank you, Dr. Allison. The one thing I'm not going to do is to reveal in advance what the speakers are going to tell you and thus spoil their talk. I hope everybody who is interested will not fail at the conclusion of this meeting to take a copy of this report to which Dr. Allison has made reference and which is largely to be the basis of the discussion this evening. We are purposely not giving these reports out until after the meeting as we don't want you to be distracted by its reading from what the several members of this panel have to tell you.

In order to get into the substance of this meeting most expeditiously and effectively I believe it will be helpful if you are first given the background of the work of research and the assemblies of information that have gone into this report. The analysis of that information and the predictions based on that analysis will

* This entire discussion is from a tape recording except where otherwise indicated.

[1] Subsidence of Peat Soils in the Everglades Region of Florida, compiled by J. C. Stephens and Lamar Johnson. For the reproduction of this report in full from the replicated form in which it was first prepared for distribution and study see, appendix page 191.

then follow. Consequently I am going to call first on Mr. J. C. Stephens of the Soil Conservation Service, U.S.D.A., who is stationed in West Palm Beach for the conduct of studies in the general field of this discussion. Before calling on Mr. Stephens I'll appreciate it if the other speakers who are to be called will occupy these chairs in a semi-circle so they will be more readily available to the questions from the floor.

MR. STEPHENS:

This is the report Dr. Allison and Mr. Wallis have referred to that has to do with the "Subsidence of Peat Soils in the Everglades Regions of Florida." I do want briefly to give you a little of the background of this work and I'll tell you just a few things that are in it—not everything, of course. In fact I won't even undertake to outline it in detail.

As indicated by the title, this is a report on subsidence of peat soil under Everglades conditions. All peat soils when they are drained subside or lose elevation and, insofar as we know, they continue to do this throughout the life of their drainage and use. Thus England has been draining such lands for I would say well onto a hundred years and these have been losing elevation at the rate of about 1 inch per year. Likewise the delta soils of the San Joaquin Valley, Sacramento and Stockton, California, have been under cultivation for some time and according to the reports from the State Experiment Station out there, they have lost about 3 tenths of a foot, or a little over three inches per year. Much of this, we are told, is associated with the deliberate burning of the surface of the land between crops or seasons for various reasons including control of weeds as well as diseases and insects.

The Department of Agriculture in 1915, knowing of the expected loss of peat soils under cultivation began an investigation of this subject in the Everglades. At about that time a number of what will be referred to as subsidence lines were run at different strategic locations in the Everglades including the Davie as well as the Okeechobee area, and out onto peat soil around Fellsmere. These were lines of levels anywhere from 1,000 to 5,000 feet in length tied into a base level at some point. These have been re-run at regular intervals since that time and you will now find in this report several graphs showing subsidence and consequent loss of surface elevation of the soil at these points thru the years. These lines, of course, reflect the subsidence of the land as its occurs in nature. Some of the loss has been due to burning, yes, and some to compaction from mechanical operations but most of it doubtless is due to natural oxidation. In any event these lines show what is actually happening and what has happened in the Glades.

Later, I believe it was about 1931 or 32, Mr. Clayton, who was here at that time, and Dr. Allison and others who were at the Experiment Station, layed out a series of controlled water-table plots on the Experiment Farm.[2] That is, these plots were laid out in such a way as to permit a close control of the water tables in the soil at definite elevations and hold it there throughout the period of study. which was some seven years. The results of these studies have definitely shown that the amount of subsidence in soils of this nature is a direct function of the depth to the water table. In other words, the lower the water table, the more rapid the subsidence. By this trend was fully indicated the desirability of holding the water table as high as feasible depending upon the crop returns. In this experimental setup yield of crops was of course measured to obtain returns on maximum as well as minimum depth to the water table.

Incidentally, along with the measurement of the loss of the surface elevation at the various levels of the water table, the carbon dioxide released from the soil also was carefully measured. It was found that the amount of gas given off by the soil under these various conditions could be correlated directly with the loss in elevation, or, with the loss of soil substance. This naturally brings up the critical question of "What causes Subsidence?" There are, of course, three or four causes for this irreversible trend, all of them accentuated by drainage.

The number one cause of subsidence, as mentioned earlier, doubtless is loss by oxidation, that is, by a slow chemical and biochemical burning. In other words organic material is not only oxidized under the influence of the light, heat and air of normal field conditions but there are certain microbes in the soil that live on

[2] Mr. F. E. Staebner, Associate Drainage Engineer in the Bureau of Agricultural Engineering at the time, who was specializing in irrigation studies, preceded Mr. Clayton in the assignment by the Bureau for a period of two or three months and helped very greatly with the actual setting up of the water table studies.—Ed.

organic matter of this type as a source of energy. Thus carbon dioxide is produced and the soil is slowly burned up.

The second important influence on soil losses under these conditions is thru rapid oxidation by fire. While this form is more conspicuous and spectacular, on the whole it is much less. In other words the losses from free burning have been much less than from the slow natural type of oxidation. Then there is the loss of elevation due to compaction as from natural shrinkage following drainage and farming operations. This usually occurs most rapidly during the first or second year of operation on the land and feathers out after the fifth year. Actually, however, this form is not so much a loss of actual soil mass, just volume. It does not concern us too much because after the initial compaction is over it does not go on and on at a fairly constant rate like that due to natural oxidation.

We have found from these water table studies, then, that the soil loss is definitely a function of depth to the water table. In other words the amount of air that is penetrating into and circulating thru the soil is a very determining factor at all times and under all conditions. Thus we have found that when land of this type is drained to a given depth, if you have it cropped on one hand and hold it undeveloped, on the other, the uncultivated sawgrass land will actually lose soil mass faster than the cultivated land. The reason for this obviously is that when the land is cultivated and compacted the circulation of air through it is reduced. Therefore, when once you drain a soil of this type it is axiomatic, in the interest of conservation, that it should be worked down and put under cultivation as soon as possible. As soon as we found this out then one of the first things that came into question was, what is happening out in the Glades, the so-called open virgin Glades, that haven't been cultivated and, supposedly, have not been drained even tho they had surface water on them only a portion of the year. How much soil are they losing? Is the water table high enough out there to prevent the loss of soil by oxidation?

In an effort to answer such questions we took the old levels that were run when the canals were first surveyed through the Everglades in 1912. Incidentally, we also had a contour map that had been made in 1942 showing the depth to rock. Then, too, we had the survey made by the Everglades Drainage District in 1925. Furthermore, we had the surveys made by the Soil Conservation Service in 1941 and 1942, as well as the recent survey made along the levee and canal alignment by the Corps of Engineers, U. S. Army, quite recently. By superimposing these various sets of values we were able to get at the amount of loss that was occurring in the so-called wild land. While we might be able to reconcile ourselves to the losses occurring in the cultivated areas it was distinctly disturbing to learn that the wild lands were losing soil mass and surface elevation at a considerably more rapid rate.

In consequence of the above findings the obvious conclusion was that a water control program which would enable the lands to receive water from Lake Okeechobee or other reservoir areas should be instituted as soon as possible so that the land either could be put under cultivation and the greatest possible gains realized from it during its lifetime of usefulness or else a higher water table be maintained in or over it with the view of giving it the greatest possible protection until it is needed for active development.

Mr. Johnson, I believe, will carry the discussion forward from this point.

MR. WALLIS:

Thank you, Mr. Stephens. I think it would be helpful to the cause of this discussion if anybody who has a question upon the conclusion of the remarks of any speaker would not hesitate to ask that question; or if those in the group who are more familiar with this whole problem than some of the others may feel that there is an important point that has not been brought out, I would appreciate very much their raising such point or points as they or others in the audience may feel have not been made as emphatic or discussed as fully as they feel should have been by the speaker. Before I ask Mr. Johnson to continue, does anyone have a question that they would like to ask Mr. Stephens at this time?

MR. JOHNSON:

For nearly one hundred years now, the people of Florida have dreamed of farming the Everglades. They have had the feeling that if they could just get out there on that rich land there could be developed one of the greatest agricultural areas in the world; and it truly has become that, within certain limits.

However, the old timers who first entered this great area found that peculiar things began to happen. For instance, every few years Bob Creech would have

to put an additional step on his house because that bottom one was forever becoming too high. He had to add another one to get down to the ground. And Bob has recognized that. The farmers out there have known it; they have known for some time that the land is losing elevation.

Mr. Stephens has told you something of why our peat lands are losing elevation; why they are losing volume. However, he didn't tell you much about the rate at which these black peats are going down. We believe the studies back through the years that he briefly outlined to you conclusively indicate that, on an average, and mark you well those words, ON AN AVERAGE, you can expect a loss thru the normal use of the Glades lands of about one foot every ten years. Again you should mark well the use of the word, NORMAL. Thus, if you had started out in those early days with soil as deep as 12 feet some of those same soils, today, because of over drainage, bad practices in agriculture, fire, and the several factors that enter into it, have lost as little as four feet and as much as six feet or more of their original depth.

Just to see how long our dream of farming the Everglades would last we proceeded to apply what we have learned up to the present time regarding subsidence. In other words, on the basis of the present soil depth remaining we have projected land use into the future along with these tendencies towards subsidence according to what we have learned from the records of the past. In this projection we assumed the lands now in cultivation have taken their initial loss and would only lose in the future say, on the average, one foot in ten years. On the wild lands, the lands that are not in use at the present time, you heard Mr. Stephens tell you just a few minutes ago that they are losing mass at a substantially more rapid rate than the soils that are now actually in use. In this forward look, therefore, we based future loss on these lands, on the assumption that they would be cultivated and put into use, within ten years—that is by 1960. At least most of us are optimistic enough to believe that if the water control program goes through as it should the whole of this presently uncultivated area within the diked agricultural section of the Flood Control Plan (points to map), will all be in use by 1960. We have also assumed that those wild, unbroken lands, because of the loss of mass they have already experienced under partial drainage, would take their initial loss soon after they are put into cultivation. This has been approximated at a foot and one-half for the first ten years and from then on they would lose elevation at the same rate as the land that is now in cultivation.

The projection of these losses was made through the years over the entire agricultural area of the Everglades. Through these projections it was found that by the year 2000 most of the agricultural area enclosed by dikes would probably have to be abandoned unless some way can be found of substantially retarding that average loss of approximately twelve inches every ten years. We assumed naturally that when the soil reaches a depth of one foot over the rock, that it no longer could be economically used, even for pasture, because of the difficulties in draining and also the difficulty, in the dry season, of properly getting water to it.

Along the margins of the glades where the peat is over sand or marl or a mixture of the two we do not have this problem because you can continue to farm those lands after the peat is gone just as you farm the sand lands of the Davie area or some of the areas marginal to the Everglades behind the Lake Worth Drainage District where in times past there was a cover of from one to several feet of peat. However, where the soil is underlain by rock it looks as if by the year 2000 most of that area cannot possibly be farmed economically. That means, of course, that we must develop these glades lands as rapidly as possible; to mine them for everything they are worth if we are to get out of them their total value as a natural resource so long as they last.

Two things, therefore, are necessary, quickly, if we are to get the most out of those peat soils. The first, is the completion of the water control system that the Corps of Engineers is now constructing. This should be completed as quickly as possible and put into operation so that the farmer on the land will have sufficiently complete water control to permit him to practice the greatest possible degree of conservation on his land thru the most efficient use of water.

We need another item very badly that is not mentioned in this report which I would like to bring to your attention at this time. Along with the development of a water control system we need a road system which the Corps of Engineers cannot provide under the Flood Control Plan; but they can be helpful. Those channels that they propose to put around and through that agricultural area will

be of great depth and considerable width. There will be an abundance of material available from them for the construction of roads. THE WATER CONTROL SYSTEM AND THE ROAD SYSTEM SHOULD BE DEVELOPED HAND IN HAND and we must have both of them as quickly as possible if we are to salvage all that we should from what remains of this great land resource. Thank you.

MR. WALLIS:

Those of you who know Lamar weren't surprised when he laid it on the table in the most horrible form that he could think of to express it. There is room for a lot of difference of opinion whether the rate at which subsidence has occurred should be projected ahead and be taken as a criteria for future trends in this respect. I hope those of you who have an honest difference of opinion with Mr. Johnson will give voice to that opinion at the appropriate time.

On the other hand, I do not feel that enough emphasis has been given to the real value of this report and the credit that is due those who have made it possible. I think this work is an outstanding credit to the Experiment Station, the Soil Conservation Service and all the other agencies that had the foresight to plan work of this nature as early as this research work was planned. Mr. Johnson and Mr. Stephens, who are the authors of this report, had as their immediate concern the consideration that should be given to subsidence of the land in the design of physical works proposed under the plan of development for the whole area upon which we are now working. They have done a job far beyond the call of duty in making available the results of earlier experimental work in this way and in making available, under this one cover in the nature of a progress report, the material contained in many other excellent reports prepared through the years on this general subject. I hope that they, and others having a similar background, will make available to the literature on this area many other such reports in the future.

According to the schedule in which we are calling on these speakers to give you a cross section of the significance of this whole problem, I now would like to have Mr. F. D. R. Parks discuss how the problem is viewed from the Engineering standpoint in the lower reaches of the Everglades area of which Dade County occupies such an important part.

MR. PARKS:

Mr. Chairman, Ladies and Gentlemen: As you are probably aware, most of my time is spent in the flood control program down in the Miami area, and this is influenced to quite a considerable extent by the tendency of organic soils to shrink under drainage and use. First, however, I want to make a personal correction on this program. I am not the County Engineer but more of a water-control engineer instead. Mr. D. A. Anderson is the County Engineer in Dade County and in charge of the program I am talking about. We also have a salt encroachment situation in the ground water supply down there that is related to this subsidence problem in a way that I will tell you about.

First of all, I would like to emphasize that we have some good marl land down in South Dade County. I emphasize this because I don't want to leave the impression that we don't have any good, permanent farm land down there; that all of it is going to subside like some of our lands out in the Everglades do. In other words we're going to have a "bread basket" down there when much of what we now have in the back country has largely faded away.

As most of you know we have some very low areas that people try to farm right around the City of Miami, 2 to 4 feet above sea level. This, of course, gets in the way of our salt encroachment program because we have some dams in the canals to back up the water and to hold the freshwater head high enough above sea level to keep salt water out for purposes of safeguarding our well and domestic water supplies which come from large wells and for commercial industries along the canals themselves. We have some farmers in this area, so-called farmers, for they do farm part of the time, that is sporadically. They like the land that is right close to the canal and so they try to farm in this area. Think they, well, this water is backed up on us in a way that hasn't been observed earlier.

It is precisely on account of this water control program that we have made some detailed field measurements in a few of those areas. Some of the older measurements or levels were made not with that in mind. However, the newer ones were made with this problem very definitely in mind and it was found that over some of those areas during the past 11 years the surface of the land has subsided 0.9 to 1 foot, which falls very closely in line with the chart that Mr. Stephens and Mr. Johnson

came up with on the rate of subsidence in relation to the depth to the water table. They made that comparison for the few points we have measurements on and have found that several of our points fall on one side of the curve and a couple on the other side. And so we find that our subsidence values fall pretty close to the averages they have established. Consequently, I think their observations and conclusions are all right.

There is another point of particular concern to us. We have another problem down there that is quite different from that around the lake area in the Upper Glades in that we can't pump effectively either for drainage or irrigation. We have a seepage condition, a very porous underlying rock, that makes the situation exceedingly bad because we cannot nearly provide the degree of water control that can be practiced in the Upper Glades area around the lake. I believe that is all I have to say about this general problem right now. Thank you.

MR. WALLIS:

Thank you Mr. Parks. Does anyone have a question they would like to ask Mr. Parks? I will now call on Dr. Herman Gunter, State Geologist, to discuss how the geology of Southern Florida influences the water conservation problem and consequently, the soil conservation program in this extensive area.

DR. GUNTER:

Mr. Chairman, Ladies and Gentlemen: Dr. Allison did not give me but six months to prepare for this discussion so I am therefore at a bit of a loss as to what to say and how to say it! (Laughter.) Naturally enough, I turned to colleagues of mine down here in the Miami territory for help because the U. S. Geological Survey has cooperated with the Florida State Geological Survey in the study of the geology and hydrology of the southern extremity of peninsular Florida almost continuously since 1930 or 1931. Much of the detailed knowledge of the geology of the area was developed during this study and these notes are largely based on unpublished work of members of the U. S. Geological Survey, particularly Mr. Melvin Schroeder. And so, between us, in this particular instance, this statement has been prepared which I hope you will not mind our reading just to keep the facts straight and in order to get through on time.

[3] The area under discussion by this panel is a part of a larger geologic unit that includes most of the Everglades as far north as the northern Broward County line and the coastal ridge from West Palm Beach southward along the entire lower East Coast. In general, these formations compose a mass of sediments that lie upon the Hawthorn formation of middle Miocene age, and which are generally thickest in the coastal areas.

GEOLOGIC FORMATIONS

These shallow formations are the foundation upon which the soils of the area have been developed by deposition of peat and by the weathering of these rocks. The rocks compose a single hydrologic unit of permeable materials ranging in age from upper Miocene through Pleistocene. The base of the aquifer is set not by formation boundaries but by differences in hydrologic properties of the sediments, and is placed at the top of the impermeable greenish marl of the Tamiami formation. The following formations, from oldest to youngest, are present: the Miocene Tamiami formation (permeable portions), Caloosahatchee marl, as small scattered erosional remnants and isolated reefs of Pliocene age, and the Pleistocene which is represented by the Fort Thompson formation (southern part), Key Largo limestone, the Anastasia formation, the Miami oolite and the Pamlico sand.

TAMIAMI FORMATION

The Tamiami formation which crops out at the surface in Collier County underlies the entire southeast Florida area. The formation is divisible lithologically and hydrologically into two units. The lower unit is composed of impermeable greenish marl and constitutes the top of the artesian system in southern Florida. The upper portion, a very shelly, marly sand, where it has locally been altered by ground water to a highly permeable solution riddled sandy limestone of calcareous sandstone constitutes the basal part of the aquifer of the area.

[3] Taken from a prepared statement from this point.

CALOOSAHATCHEE MARL

The Caloosahatchee marl is known to extend southward from Lake Okeechobee for several miles where it occurs as thin permeable limestone and sandstone reefs or shoe-string sands.

FORT THOMPSON FORMATION

The Fort Thompson formation is the chief component of the South Florida aquifer. In Dade and Broward counties the formation is predominantly light gray to cream-colored fossiliferous, marine, sandy limestone and calcareous sandstone with thin inter-beds of gray and tan fresh water limestone. The entire section has been subjected to solution by moving ground water so that the material is a cavity-riddled mass of very permeable rock. Cavities may in places reach a few feet in diameter and are sometimes filled with sand which tends to decrease permeability. In general, the sand content increases toward the coast.

The Fort Thompson formation is one of the most highly permeable rocks in the world and compares in permeability to very clean well-sorted coarse gravel. It is the chief source of water for larger producing wells in Dade and Broward counties.

ANASTASIA FORMATION

North of Boca Raton in coastal areas and a few miles inland the Anastasia formation forms a large part of the aquifer of the coastal ridges. It is usually composed of sandy limestone, calcareous sandstone and shelly sand, in part coquinoid, with the amount of sand increasing in coastal areas. The formation has also become riddled with solution cavities by ground-water movement, so that it is an excellent source of water in coastal areas in Palm Beach County.

KEY LARGO LIMESTONE

The Key Largo limestone forms the Florida Keys extending from Soldier Key southward to include Bahia Honda. It is relatively unimportant since it usually yields salty sea water to wells. It is composed mainly of coral heads and other reef building material of very permeable character.

MIAMI OOLITE

The Miami oolite is the surface rock which blankets nearly all of Dade County, parts of eastern and southern Broward County, the southern mainland area of Monroe County along with the lower Florida Keys and a small area along the Collier-Monroe county-line. The Miami oolite is usually a white to yellow oolitic, cross-bedded limestone containing varying amounts of sand usually in cavities. In general, the formation is less permeable than the underlying Fort Thompson formation. However, it is the source of supply for many shallow irrigation wells in the Miami area.

PAMLICO SAND

The Pamlico sand is a fine to coarse terrace sand deposit which covers much of the Everglades north of the approximate latitude of Fort Lauderdale, and blankets coastal areas as far south as Coral Gables. It is a shallow source of supply for small sand point wells.

OCCURRENCE OF GROUND WATER

All the water which supplies southern Florida is derived from local precipitation. When rain falls to the surface a part is evaporated, a part is used by plants, a portion runs off into lakes and canals, and the remainder percolates downward through surface materials to the water table. The water table is the surface below which the rocks are completely saturated. Ground water is stored in openings in the rock and moves laterally and vertically under gravitational influence to points of discharge in streams, canals, lakes and oceans. It is this natural discharge which maintains surface water body levels during dry seasons.

The water contained in the ground-water aquifers occurs under non-artesian or water table conditions because no impermeable material overlies the aquifer and the water in a well penetrating the aquifer will not rise above the point where water was encountered. The water table is represented by the water surface in wells and holes which are deep enough to penetrate it.

The water table fluctuates in response to rainfall in the area and may vary considerably from year to year. Also, the water table within the year is high during the rainy season of May through October and low during the period of November through April. It is during the period of low water stage that soils are deficient in water, oxidation is greatest and the aquifer underlying the coastal areas is subject to accelerated salt water contamination from the ocean.

GROUND WATER USE

The shallow formations are the important non-artesian source of water in southeastern Florida. Nearly every municipality in Dade, Broward, and Palm Beach counties taps this highly productive reservoir for its municipal supply. In addition, thousands of smaller wells are drilled into the aquifer for domestic, irrigational, industrial, cooling or stock watering purposes.

Water wells are moderate in cost since usually little casing is required to complete a well. However, in coastal areas where sand is more prevalent, more casing and sometimes screens are necessary for completion. Wells may be pumped at high rates over long periods of time and, due to the high permeability of the aquifer, only small drawdowns will result.

The ground-water pumpage in 1950 for the three counties is estimated at 140 million gallons per day. Of this total Dade County consumes about 100 million gallons per day. Following is an estimate of the various usages of ground water in Dade County for 1950 in gallons per day:

Municipal	65 million
Industrial	20 million
Rural and irrigation	15 million

The above total pumpage for 1950 is nearly twice the amount consumed in Dade County in 1945.

It is expected that in the near future the daily water use in this same area will exceed 200 million gallons. This demand can be obtained from ground water, provided that certain conservation steps are taken in some areas. It is this phase of the general question of water supply that ties in so directly and so definitely with the subject of this panel discussion.

MR. WALLIS:

Thank you, Dr. Gunter, for that paper. Interspersed though it was with all those 5-dollar words it was still quite readily understandable. I think that it was very helpful in drawing the physical picture that we are trying to develop with the many complex relationships which exist in this extensive problem.

Mr. John Pickett, who I know Luther Jones, if he were presiding, would refer to as the "muck rat", will now discuss the transitions that have been observed by him during his many years in the Everglades and give you his opinion of what we should expect in the future.

MR. PICKETT:

Thank you Mr. Wallis and Mr. Jones for that really "down to earth" introduction. I didn't realize that you and Luther could place in me such an exceeding amount of trust. Gentlemen, as I think of this problem before us, I am reminded of one of the remarks of Sir Isaac Newton when he said "As I play along the seashore picking up pebbles, picking up a shell more beautiful than the rest, I pay no attention to the great sea of truth that lies before me." I have studied this very excellent report by Messrs. Stephens and Johnson very carefully. I have gone over it with the view of trying, if possible, to tear it to pieces. Unfortunately, gentlemen, I concur. I can find little in it of which I can disapprove.

However, in studying the initial shrinkage of the Everglades soils, that is, as shown by sections taken before 1924-1925, I've found myself confronted with this question. In making such physical observations as surface elevations on these glades while in a virgin state during those early years are they accurate and at all com-

parable even to those of more recent years. In other words, gentlement, no soil you ever stepped on could be less stable, for if you stood on the soil *here* it would rise up over *there*. The question of the engineer always has been, therefore, "where and how should we hold the level rod?" That is to say, if we were to take the elevation of what should be regarded as the very top of the parent soil, should we set the level rod down and let it come to rest by its own weight? In all of this I am reminded of a conversation I had with one of the first men to run a level over the Everglades, a Mr. Richard F. Ensey of Stuart, Florida. He informed me he had nailed cross laths to the bottom of his level rod so it would not sink and that in this way he could get the true surface elevation of the glades. But now, gentlemen, was this the true elevation? When first the drainage came in what did we lose? Did we lose actual soil mass or did we simply lose elevation of water?

In studies that have been made since 1924 and 1925 I have no argument or question. In fact I have observed this subsidence thru the years but have never made nearly as careful study of it as these gentlemen have. However, I have noticed different rates of subsidence and must agree to the influences causing them. Therefore the only real hope I can find in this report that is under discussion this evening is the observations made in respect to the influence of high water tables on this tendency. Thus for over a period of ten or 12 years there was practically no subsidence on those plots at the Experiment Station. In fact, as I recall, that particular graph showed only 3/100 of a foot or a rate of loss of only about 1/100 foot in 3 years. That, gentlemen, I consider to be very small. On those particular pasture plots, too, you could have seen some very fine grass even with the very high water table that was maintained. Such findings I consider very much worth while.

I am very much disappointed, however, in all these studies to find that they were made only on "saw grass" and "willow-elder" types of land. In other words I saw no graphs on the subsidence of the so-called "custard apple" muck. It is my opinion that there exists, possibly in the files of the County Engineer, Jake Boyd, certain soundings that have been made showing depth of this muck using the rock and the canal levels as the datum. This is from the vicinity of Hendry County, around past Ritta, on around the south shore of the lake and up the southeast shore as far as Canal Point. If there is any possible way to obtain these early records I think it would be well to do so. It would indeed be fine if Palm Beach County would make these records available to the proper supervisors and testers. It would be a great public service, and would give us the basis for a very excellent report of a similar nature on this type of soil. The above soundings were made in saw grass peat, willow and elder peaty-muck, and custard apple muck over a distance of at least 35 miles. So I very strongly urge this committee or group to take steps to ascertain the availability of this data and information. Thank you.

MR. WALLIS:

Thank you, John. Mr. Mounts will now present observations relating to this problem that he has made as County Agricultural Agent of Palm Beach County through a quarter-century of extension work in the Everglades area.

MR. MOUNTS:

Mr. Chairman, Ladies and Gentlemen: Unlike Dr. Gunter, I didn't have 6 months notice of what I was going to talk about when I got up here. In fact I found out what I was supposed to talk about when the Chairman introduced me as I stand before you this evening. Dr. Allison mentioned to me about a week ago that he would like to have me on this panel, and he told me this afternoon that I was on it. And so this evening I found out that I am to make some comments on what I have observed in the quarter century that I have worked with the Agricultural Extension Service in Palm Beach County.

It seems to me that the problem of subsidence can be reasonably well projected into the future—as to what will happen and what can be expected in the years to come, from the use of these lands. It is true that we have made a lot of progress in the Everglades in changing over from a strictly vegetable type of agriculture to one involving the development of extensive areas of pasture land. The comments that have been made and supplemented by John Pickett concerning soil subsidence trends under pasture conditions give us some indication of what we may expect or at least of what we could do in the future. In my opinion, therefore, it is going to be a matter of the proper utilization and management of these soils and the formulation of an opinion as to what investors can expect to do with them in future years.

As your County Agricultural agent I have had a great many inquiries about the possibilities of agricultural development out in the Everglades and so we present and discuss with them this plan of the U. S. Army engineers. However, until we really get the so-called agricultural area enclosed and the control facilities operating efficiently there isn't too much that I, as the County Agent, can tell these people regarding these lands, especially those lying back from the roads in the really undeveloped sections. And so, until we have some assurance that the water control facilities are going to be installed and the roads built reasonably soon there isn't much that can be done except to listen to the talk of speculators. But I, as County Agent, am interested in people who are going out there to develop these lands and make sufficient money from these essentially rich soils to pay for the cost of this extensive flood control program that we are seeing projected right here this evening. And I have every confidence that if this plan is developed, as I know it can be, and will be, that we can get these lands developed and that we can develop them as rapidly as Mr. Johnson, here, has suggested that they should be; also that we will be able to utilize them in a way to make them pay off in an economically sound and successful manner. Thank you.

MR. WALLIS:

Thank you, Mr. Mounts. The next several speakers are those actually using the land, dirt farmers, so to speak. I think there should be much interest in listening to their viepoints and learning what plans they may have to cope with the problems that have been outlined by the previous speakers. We would like first to hear from George A. Wedgworth, a young farmer from the Belle Glade area whom we all know very well and whose father, before him, we knew even better.

MR. WEDGWORTH:

I don't feel that I am really very well qualified to get up here and undertake to speak to you on this subject. In fact, I must apologize for not having prepared a talk. To tell you the truth I feel more like a student, with you as the instructors; and I want to sit back and ask questions.

I do have one important question that I would like to have answered before I leave tonight in that, to me, it is a very pessimistic report which states that by the year two thousand most of the lands of the Everglades will be totally unproductive or will be right down on the limerock. That is decidedly pessimistic because I have been rather hoping still to be around at that time and such a viewpoint leaves me a bit up in the air as to what I will be doing then. They haven't given me any answer as to prevention or cure.

I think one of the good points that has been brought out was by John Pickett in his remarks about these subsidence trends on pasture lands. I have noticed the same thing on two of our farms under pasture development where pasture areas happen to be next to celery fields in which the water table is held relatively high. While there hasn't been a level put on the surfaces of these soils, it is apparent just from simple observation that there hasn't been nearly the subsidence in these pasture lots with a fairly high water table that there has been under cultivated land. I believe that if we look at this whole question from the standpoint of pasture development it will be a little more optimistic than Mr. Johnson puts it. Frankly, Mr. Johnson scared me tonight, but I guess that either he or I will get straightened out before the evening is over.

MR. WALLIS:

Thank you very much, George. That was a very helpful contribution. We will now hear from Mr. Harrison Raoul who has had a great amount of experience with widely different types of agriculture in the Everglades and is presently manager of Hillsboro Plantation that is located well down in the middle Glades.

MR. RAOUL:

I am inclined to agree with my friend, George Wedgworth, and hope Mr. Johnson gets himself straightened out before the evening is over. I represent a company that has a very substantial investment in muck land in the Everglades. This is a long term investment. We didn't come in to make our money quick and then get out. We didn't come in to mine this good land, Mr. Johnson notwithstanding. And I sincerely hope we can do a better job than that with our holdings. Frankly, I think that we can. I also feel, with equal frankness, and this certainly is a self-criticism on farming in the Everglades, that though I've only farmed here twelve years, I am now certainly conscious of having mined the land while I have been out there—

from a drainage standpoint as well as others. This is because I just haven't known what I was doing. Now these studies have been made and certain very important trends have been brought to our attention and we begin to see what we are doing to our own natural resources.

Now we are told that there is nothing we can do about it, that it is going on and on in spite of anything we can do. Well, I just frankly refuse to believe it. I think we *can* do something with scientific brains at the back of this problem; and I certainly hope that our company can make its contribution towards doing it. The first way we are trying to do something about it is this. We are told, and we certainly have observed that if you can maintain a high water table in your cultivated area your land does not subside as fast as it does if you keep a low water table. So therefore, what crops can you grow on a high water table?

It seems to me that is the first obvious solution if we are going to farm and not mine the land; keep a high water table. Well, we find that celery grows well on and, in fact, requires a very high water table; so we're growing a lot of celery. We also find that kenaf, though a rather new crop, has a lot of water tolerance and will grow in the summer time when it is quite easy to hold a high water table, and so maybe it is another crop. We don't know for sure whether kenaf will grow forever and ever in the Everglades, but we are certainly interested in the crop and willing to try it.

We also find that maybe there is a possibility of growing rice in the Everglades. We are not too sure that we can get this crop to grow but we do have two eighty-acre experimental plots under way and right now we think that it might do quite well. Of course we would like this very much because you grow rice under at least partial flooding. Now I don't know any better way to keep the land from subsiding than what these gentlemen have told me, than keeping it under water. So therefore, it seems to me that rice might be a very good crop if we can work the problems out that are connected with its culture. Please understand, we are not ready to say that we can grow rice yet, but we are ready to say that it looks like we can and the possibilities certainly should justify further investigation.

Cattle, yes, we have found that our pasture, particularly our permanent pastures, do much better with a high water table than they do with a low water table insofar as producing tonnage of grass and hence more beef per acre, and that is the business we're in, growing more beef per acre.

So, we certainly think that vegetables such as celery and others with a high water tolerance have a very important place. We also think that such a fiber crop as kenaf also has its place. And we believe that rice may have a very definite rotational place in our program. Finally, we firmly believe, from the long-term investment standpoint, that our investment is sound and can be carried on. Thank you.

MR. WALLIS:

Thank you, Harrison. We will now listen to Mr. Luther Jones, publisher, realtor and erstwhile farmer.

MR. JONES:

I knew that I was going to be here but I didn't know that I was going to be called on. However, I am glad I am. As a newspaper man and as a real estate peddler this report did more than scare me. I have been active for the past six or eight months trying to induce wealthy Yankees to come down here and invest some of their money. Now, how am I going to tell them that this land is not going to last for more than fifty years, some of it much less. I feel something like Harrison. I have a great deal of respect for Lamar and Mr. Stephens but I'm not going to let myself believe what they have said.

Now there is a great bunch of what I would like to refer to as Brass Hats present. PhD.'s, why these are as thick around here as fleas on a Vinegar Bend dog; and it is hard to get any of you to make a definite statement so anybody could pin you down.[4] And yet I love every one of you and the work that you are doing

[4] May it not be that the *statement* which has been made long since and repeated many times by his friends, "The Brass Hats", regarding the unavoidable subsidence, under drainage and use, of organic soils such as make up the vast reaches of the Everglades, and which is the principle topic of discussion this evening, is already *TOO definite* for Luther? In any event, it will be interesting to see what he has to say from here on out.—Ed.

because I have induced a considerable number of well-to-do gentlemen from the north, during the past several months, to put their money in this muck we are talking about tonight. And it is only because of my confidence in you and in what you are doing that I can go back and face any of them tomorrow despite Lamar's and Stephens' report. I'll tell you why. I have a great deal of respect for American ingenuity and American brains. And I'm telling you gentlemen here tonight that I expect you to disprove what Lamar Johnson and Mr. Stephens have said. I expect you to show us a way out. I know there is a way out. And I expect you to show us that way. We have an inkling of how it is to be done but we don't know for sure and I know that you same gentlemen here tonight within five minutes are going to begin to tell us how to do it.

Suppose it is fifty years. You can pay for your land in five years and you've got forty-five years left to make a profit out of it. Now honestly, gentlemen, I have a great deal of confidence in the ability of men such as yourself coupled with farmers like Wedgworth and many others in the Glades to find that instead of the year 2000 it will be 2050. However, for me, along with some of the rest of you who haven't any more hair than I have, the year 2000 is not going to hold a great deal of personal interest. But there will be farmers out there in the year 2000; and I believe there will be those out there on the land who will be farming the Everglades in the year 2050.

There is one thing I want to say to Dr. Allison and to the Soil Science Society of Florida and it is this: Representing the Florida State Chamber of Commerce, as Chairman of its Water Control Committee, I want to thank them for bringing these problems before us and having them discussed. That is one of the ways we are going to find the cure. Now Lamar and Mr. Stephens remind me of the doctor who tells an old gink my age or a little older, who has had heart trouble, that according to the records he will most certainly lie down and die within five years, or between now and then or maybe day after tomorrow, if he don't change his ways. We are not only going to change our ways of farming in the Glades but you, gentlemen, are going to tell us how to do it. I thank you.

MR. WALLIS:

Thank you Luther. After such a confession we know you are going to live to a ripe old age. We will now listen to Mr. John Tiedtke.

MR. TIEDTKE:

I am glad Luther Jones spoke first because he said about everything I had to say and now I don't need to take up much of your time. I have had enough experience with farming in the Everglades to see that the land levels are actually down a little.

Some of our fields that we used to be able to mole drain satisfactorily, cannot now be drained in this manner; and some of the fields that we used to run a drag-line down inside of the ditch now have to be dynamited. So in my short span of farming in the Glades, subsidence has been observed to be a little more than a rumor. However, it took this report of the engineers tonight to turn it into a concrete fact that you can measure and I must say that I was startled by several things in it. Not because the rate of subsidence was any greater in the tables of the report than the things that it seems have happened out on our farms, but because they have been working on the thing since 1936.

I feel that since it does take a number of years to develop something that a Ph.D. will put his name to we are all very fortunate for the foresighted vision way back in 1936 that got this study going so that today we have this report. In 1936 and 1937 none of the farmers that I knew were talking about subsidence. If they knew about it they didn't seem concerned about it and there was apparently sufficient foresight on the part of the Agricultural Experiment Station in those days to justify starting an experiment that would hold water, figuratively as well as literally.[5]

This report, I think, is extremely valuable. It seems to me that if we can do all the miraculous things we do, make all the tests we make with all manner of bugs

[5] As an indication that serious thought had been given to the subsidence of Everglades soils under drainage and cultivation long before 1936, a part of the summary of the first bulletin of the Everglades Experiment Station (Fla. Expt. Sta. Bul. 190, 1927) is reproduced on page 190 of the appendix of this volume facing the recent report on this subject which was discussed at length during the evening and which is reproduced in full on pp. 191 to 237.—Ed.

bacteria, viruses, etc., if there is a certain type of action going on in the soil that we don't like, someone ought to be able to think up a way to stop it. I really do have hope.

As far as the general task is concerned, practically, I think we have two entirely different problems. They have been mentioned briefly. One is that of the farmer whose interest, as a citizen, is to make an investment in the land he has and to come out with a little more than he put into it each year. We have all the good wishes in the world for posterity but we do have to eat and so we have to go out there and find a way that will pay off. So we are going to have to find the best way possible, of course, for successful land use but the plan also has to be practical from a day to day standpoint.

However, from the standpoint of acreage a far greater problem lies in the vast expanse of undeveloped Everglades peat and I will touch on this only briefly. I agree that is not an additional problem if it means the simple destruction of the land. However, I think that, without any question, it is a matter of conservation of natural resources and that conservation is certainly going to be worth the money it will cost to put this program into effect. I'm not at all sure that the Flood Control Program is going to prevent all flooding. There are some of you here who know much more about this than I do and can answer that question much better than I can. But I do believe that it is within the purview of the Federal Government's interest to jump into this problem with both feet because the time may come when we are not just feeding the present population of the United States. It is possible that we may be feeding 50 percent more people 50 years from now and this land will then have ever-increasing demands made on it for the production of greater and greater amounts of food for consumption at home as well, perhaps, as abroad.

MR. WALLIS:

Thank you, Mr. Tiedtke. Now I'd like to call on Mr. Leo L. Burnet, Chief, Engineering Division, Jacksonville, Fla. District, Corps of Engineers, U. S. Army, Jacksonville, Fla., to present to you the viewpoint on this problem of his Corps as an agency of the Federal Government.

MR. BURNET:

Mr. Chairman, Ladies and Gentlemen, this is the first opportunity that I have had to appear before the Soil Science Society and I want to say right here that I really appreciate it. As many of you know, I'm a very far cry from an expert on the conservation of organic soil. I'm sure that I'm going to learn more tonight than I'm going to contribute.

[6] However, I'd like to refer back to may first encounter with organic soils which was about 35 years ago when I was in an Army Camp in New Jersey. They had land there they referred to as bogs, or sometimes cranberry bogs because they used to grow cranberries on them. The cranberries grew on little bushes just a few feet high. They had these bogs arranged so that they would flood them in the winter. cranberry bushes and all, to a depth of several feet. They would freeze over, and I have often gone ice-skating on them. When spring came they would remove the boards of the temporary dams, drain the water off, and the cranberry bushes would leaf out, bloom, and bear, without damage from being inundated.

Many of these bogs contain peat. From childhood association with families who had come from Ireland, I learned that on many of the farms in Ireland they had peat formations which they would use for fuel, cutting the peat in slabs similar to our lawn sod, drying it, and storing it for winter use. I had visions of developing a big business as soon as I got out of this man's Army in the matter of mining this peat. I got a shovel and sliced out a cubic foot or two of the material and put it aside to dry. It was soaking wet and seemed to remain that way for so long that I almost forgot about it. When I did look at it a month or two later, it had shriveled up to about nothing, and looked something like Grandpa's beard.

I next encountered organic soils in Wisconsin, where they were also referred to as bog land. They were not covered with water, but the water just about stood on the surface and the earth seemed to rise up in circular mounds. If you would jump on them, the mass would quake. This proved be very valuable farm land when drained, and the drainage seemed not to present a very great problem as the area of the bogs was quite small. They would simply run lines of 6-inch drain tile, about 50 feet apart and around 4 feet deep, draining the main line off into a ditch.

[6] Taken from a prepared statement from this point.

My first knowledge of the Florida Everglades came from my grade-school study of geography. The Florida Everglades was described as a vast area of slimy ooze, literally crawling with crocodiles and all sorts of poisonous snakes, lizards, and what-have-you. The very name Everglades was mentioned in a hushed tone as being something that denoted horror, destruction, and death. We were led to believe by our teacher that if one ventured so much as to stick his foot in the Everglades he would soon be sucked into it, and if poisonous demons didn't get him first, he would be sucked under, and his remains would be discovered at some future geological age.

The Glades land suitable for long-time agriculture, now generally known as the agricultural area, is amazing in its productivity when properly drained. Unfortunately, as quickly as it is properly drained oxidation commences, with the resulting subsidence or lowering of the surface. I am sure you will all agree that this subsidence is a known fact wherever organic soils are drained. Since the initiation of the Central and Southern Florida Project for Flood Control and Other Purposes, the Corps of Engineers has made hundreds of laboratory tests on the organic or peat soils. While there is some small difference between the different classes of peat, such as Everglades Peat and Loxahatchee Peat, generally speaking our tests indicate that the field moisture content in terms of oven-dry weight is about 600 percent. The oven-dry weight amounts to only 8.6 pounds per cubic foot. More important, the average organic content we have found to be 77 percent. In other words, if we would take a sample, then dry it, determine the dry weight, then burn it, we would find that 77 percent of the dry weight would burn up. We can therefore say that 77 percent of the peat lands is subject to slow oxidation when drained. Complete oxidation of a peat bed with an original depth of 4 feet would leave only 1 foot. The subsidence of peat soils under cultivation is real and indisputable, whether those soils be in the State of Florida or any other place in the world. While a great deal of very valuable research has been done to determine the rate of subsidence, that rate still must be considered a variable amount. The rate would vary in different parts of the country, due to varying climatic conditions. Right here in Florida the research I have already mentioned indicates considerable variation, depending upon to what use the land is put. Thus, lands subject to a high state of cultivation subside more rapidly than do those used for pasture lands. Those used for certain crops subside more rapidly than those for other crops. However, it seems apparent that the rate of subsidence of our drained Florida organic soils is very closely associated with the depth of the water table maintained in those soils. The lower the water table, the greater the subsidence, and vice versa. Therefore, the best possible conservation of our organic soils would demand the maintenance of a water table just as high as the crop being grown will permit, with a still higher water table when the lands are idle.

We of the Corps of Engineers like to feel that we have earned the name of being public servants. I say "earned" because I don't believe anyone is entitled to be called a public servant unless he actually *serves* the public. In this public service, it is absolutely necessary that we take cognizance of the problems connected with farming organic soils, including the matter of subsidence, and I would like to explain briefly just how we are so concerned and what we are doing about it. In the agricultural area we are going to dig many canals with levees on each side. These leveed canals will serve as the main drainage arteries in the agricultural area. Water will be fed into these canals by privately owned and operated drainage works to serve the adjacent lands. In turn, the water will be removed from these main canals by large pumping stations, to be installed by the Federal Government. The levees on each side of the main canals will be built on top of a layer of peat with varying thickness, depending upon the location. Some of the levees will contain peat in the embankment, but it is our present plan that all of these levees will be covered by a minimum 2-foot thickness of rock and marl. To allow for the subsidence and compression of the peat, the construction grade or crown elevation of the levees will be increased in the amount of 50 percent of the depth of the peat contained in or beneath them. Thus, all of the peat in the levees or below the levees can subside by 50 percent of its depth and the levees will still be high enough. Then the problem is, what is going to happen when these adjacent lands subside some time in the future? Will these main canals still function as drainage ways for the adjacent lands after they subside? The answer is "Yes", although the adjacent landowners may have to pump against a little higher head as their lands become lower. If at some future time the agricultural lands subside to the extent that pumping costs are greatly increased, and it would become economically feasible

to deepen the canals in order to lower their surface water profiles, it should not be too difficult to have a study authorized in the way of a review report of the project towards determining whether the canals should be deepened. If such a review report would indicate that the cost of deepening the canals will be offset by appreciable benefits, it appears likely that Congress would authorize such work, just as it has been doing for many years in the past in connection with navigation channels. It is very often the case that Congress has authorized the construction of a navigation channel to a certain depth and then in later years, based on the findings of a review report, has authorized a deepening of the channel. In some cases they have authorized the same channel to be deepened several times as the needs of navigation require. Whether it will become necessary at some future date to lower the main canals due to subsidence of the lands is anybody's guess. It might be found that as the land subsides, large areas would go out of production and therefore out of drainage and the water profile of the main canals will be lowered automatically due to less water being fed into them.

We would indeed be delinquent in our planning if we did not take cognizance of the possibility of deepening the canals at some future date in the design of our large permanent structures such as the pumping stations. In view of the expected subsidence of the organic soils in the agricultural area, our planning of the pumping stations provides for a possible future lowering of the canal profiles by several feet.

MR. WALLIS:

Thank you, Leo. In promising to refrain from telling you what the speakers were going to say, I didn't say I wasn't going to make some comments after they've said it, in an endeavor to interpret or comment on their remarks. I'm very much impressed by Luther's reference to this discussion appearing to him like the situation where the Doctor tells a patient about a critical heart condition and if he doesn't mend his ways he is at death's door and won't be here for even one year. I think there is a lot of truth and thought in the analogy he drew in this connection because those who have the heart condition and don't get to hear of it from the Doctor and do what he tells them, usually don't last that long. I think that is a good message for those of you interested and concerned with the welfare and conservation of Everglades soils. You first get yourselves scared good and hard, perhaps somewhat unduly, and then you had all those fears allayed by the PhD.'s, referred to by Luther as the Brass. I don't know why there was no mention of Bureaucrats in this connection as they are usually associated in Luther's remarks with situations of this nature.

Be that as it may, there is a definite part in this program of conserving, developing and using our Everglades land resources to the very best advantage that rests on the individual owners of the land. I only hope you won't be the patient that got scared of your heart condition but didn't do anything about it. There are very definite levels of responsibility in this, but the big share of it, in my opinion, rests on the individual. There is a certain responsibility and a very definite but limited one, that has been accepted by the Federal Government and other agencies, both State and local.

Furthermore, I don't think quite the right interpretation has been placed on what Mr. Johnson said. Mr. Johnson tried to emphasize that with subsidences of from four to six feet in depth in the approximately 45 years since there has been any attempt at reclamation of the Everglades, there has been a loss, as best it can now be ascertained, of about 40 per cent of the original depth of the muck over this area; and that there is obvious need for something to be done along very carefully planned lines in the immediate future. He endeavored to emphasize that even with the projection into the future of past rates of subsidence that there is still an asset that warrants a most definite call for greater protection and more skillful utilization. At this time I'd like to call on Horace A. Bestor to present an overall summary of his views on this subject.

MR. BESTOR:

Mr. Chairman, members of the Soil Science Society, Ladies and Gentlemen: I am glad to comment on this devastation of the organic soils of the Everglades as observed thru the years of my personal experience in this remarkable area. When I was given a copy of the report that has just been reviewed, naturally I was very much interested in reading it. In doing so it gave me a very vivid impression that it is an inventory of facts representing something that is happening that is cause for real concern.

However, I'm like Mr. Jones, just naturally an optimist. I can recall coming to the Everglades when it was entirely under water. I can also recall making an examination and study of the use of the land at that time. One of the first impressions that I developed during those early days while the Everglades was still largely under water, was the great need of the land for the conservation of that water. I based such a prediction of necessity that was not too obvious at that time, on the facts of rainfall, which occurs in Florida only about 25 percent of the year, thus leaving approximately 75 percent of the year practically without rain. Therefore, before the land was converted into the vast agriculture empire as we know it today around the shores of Lake Okeechobee, the thought that was uppermost in my mind was, water conservation in relation to the moisture that was needed the year around.

This, then, was my first interest in the problems of organic soils. However, I don't know that "soil" is the right term because an organic mass such as we are working with is not properly a soil in the conventional use of the term. As a matter of fact, when you start to work with such body of decomposing and decomposed plant material you are really in a sort of soil building business! In other words, you will have to put into the material something to balance its fertility because such highly organic peats haven't much in the way of natural fertility, except nitrogen, of course—and water. I was particularly impressed with the fact that in such an organic mass under natural conditions its greatest constituent is water, and if you should take that water away from it you will have some real problems on your hands, immediately, especially in the form of an almost unbelievable degree of shrinkage.

Another of the impressions that has endured from those early days and which might enter into this problem in a practical way was that in the different areas that I had to work with in the Everglades where they were trying to move water there was no place I could find where they talked in terms of moving volumes of water; they were talking largely in terms of a "10-foot canal" or a "50-foot canal", and when one asked the meaning of that, well, that was a "big canal" and should be able to take care of a lot of water!

Now I feel this way about Florida. Florida's assets are largely her climate and her abundant supply of good water. And jolting as this report sounds with regard to our being out of business in the Everglades in the year 2000, I don't believe that, especially when you recall that there are various kinds of business. As a matter of fact I don't find the main points that are contained in that report to be particularly new if you look back thru the various reports having to do with the reclamation of the Everglades such as those of the Department of Agriculture and many others made during what we might call, for want of a better term, the "dark ages". Practically all the comments ever made on the possibility of using Florida's organic lands were adverse. It couldn't be done; and they talked in those early days about this subsidence of the land surface that we've been discussing at length this evening.

There is no denying the facts of this inventory. It is a drastic picture and has much meaning. However, the principal conclusion that I've developed thru the years in trying to compromise the use of this land with its ultimate destruction as a forthright agricultural asset is that you have to care for it through its water. Furthermore, if you are going to be successful in soil building on this land you can be sure that it is going to be a very painstaking job. We can't continue to exploit it as we've been exploiting it in the past. In order to make that point in a report that I made on how to handle water, I spoke particularly about a place to put water. I'm speaking now in reference to my experience in developing all the drained areas that border on Lake Okeechobee and of having to do with making studies of how to handle the land in relation to water. Such studies were based on the actual quantities of water that had to be moved. In designing those canals, there were certain depths, and certain elevations and certain operations that had to be considered which would preserve the growing quality of the soil and the necessary equilibrium between the soil and the water. So it required a lot of time in designing and laying out a system which would service the lands both in relation to drainage and irrigation requirements thru those periods during which the rainfall was in excess or insufficient.

Now to get more directly at a description of what organic lands are in terms of the sawgrass peat of the Everglades which we are largely discussing, it must be remembered that it was developed through thousands and thousands of years of growth and dying back and growth and dying back of the native sawgrass into the

organic mass. On this account the structure of this soil is largely vertical to that growth. In all the practical experience I have had in the manipulation of water in relation to the growth that made that organic material is was found to be vertical, the movement of the vegetation in falling down being negligible. This means that such structures should always be taken into account in any and all operations designed to move the moisture thru the soil whether in (irrigation) or out (drainage). Anybody that has anything to do with handling water under these conditions understands that for it isn't a new theory. It's a fundamental fact that has to be faced.

The story of this loss by subsidence isn't new, as has already been observed. It dates back to the "dark age" referred to earlier. It has been told to the people of Florida from the beginning. When I came to South Florida I promised exploitation of the soil resources of the Everglades, and I don't view that as any more serious than I do the exploitation of its waters. The water supply of Florida is being exploited and destroyed in the same way as the organic soils. The principal reason we are losing our lands is because we are not paying attention to the fundamental facts of how they must be handled. That isn't something that some long-bearded scientist is going to tell us some 5 or 10 years from now; you have been told that for the last 25 years that I know of through my own experience.

Now they tell you that there are other causes for that loss and there has been some proof that all of that loss is not necessary. The operating of your pumps and the control of your ditches is, of course, your responsibility but it has been the too common thought that if the ditches were pumped dry you had more of a chance for drainage from the land or you could pump that ditch dry and then not pump for another week and save a few dollars. If you were to operate your water system like we had planned and as it should have been handled, a large portion of that type of operation would have been avoided.

Another thing is that in efforts at conservation of these organic lands the soil must get back just as much of the organic material as possible that has been taken out of it through cultivation. You can restore or prevent a good deal of the subsidence by putting back all the plant debris that can be made available for the purpose. In doing this please keep in mind that as you return these materials to the soil and otherwise maintain its fertility you are adding to the stabilization of Florida and to the ultimate realization of this great plan of reclamation. In my opinion the land can be saved.

Now you've got another drastic type of loss in the use of organic soils. Let us consider virgin land. The first time you remove water through drainage you are going to initiate a natural compaction. Thus in the 12 years of experience on organic soils with which I've had to do, that initial loss has amounted to about a foot in the first 18 months of drainage when the free water actually leaves the top soil and settles down into the more compact soil. Of course you have not lost anything like that amount of material, it has been largely water and elevation that has disappeared. In another 24 to 30 months that same type of compaction loss amounts to about another foot and one-half. That is the experience that I have had in the development of the drainage districts I have had something to do with.

I have also had something to do with some of the experiments being carried out, for instance certain studies that have been carried out by the Experimental Station; and I have listened quite carefully to the discussion of water tables. I have the feeling that there is a misunderstanding of what the water table actually means. It certainly don't mean that you can have the water table right up near the top of the land as Mr. Raoul has said. In any event such high water tables will certainly place definite limits on what you can do. They also limit you as to the rate at which you can move water. Furthermore, I don't care what kind of plant growth you put on any kind of land and particularly organic land, of course, it can't do anything at all unless the roots can breathe. The greatest factor in handling water in soil is not to waste your moisture and provide irrigation in that soil only to such a degree that when the roots go down into it they will still find a breathing space. Thus, if you have what is commonly known as a "high" water table within your land all the roots of most plants that go down to that water table will assuredly make an effort to turn up. More likely they will die. These roots under such conditions will turn up for the simple reason they must have air and there is no oxygen, whatsoever, in the ground water of such soils.

Another important point to keep in mind in designing the water control features for a particular area and that is whether you are going to raise rice, celery, beans, or sugar cane, because the requirements of these crops are God-given and you must

deal with them in figuring your reclamation requirements. It becomes a matter of handling a certain amount of water under certain conditions. The principal overall condition in South Florida is, of course, the exceedingly flat terrain with which we have to work. So, regardless of the crop that you decide to grow, the fact remians that your ultimate design must be based on the true requirements of such crops and not on some quick whim that you are simply going to raise certain crops. All of this, of course, does not need to be confused with the factor of water duty to a plant. There is a vast difference between the water requirements of vegetable crops, such as celery, and that of sugar cane or some other crop, both in their structure and in the way they get their water and their food from the soil.

Now if you are going to drain land, drain it in a true sense, that is, you are going to regulate the moisture in the soil in a way that will provide an optimum balance for the life processes within the plant. If you choose, therefore, you can design a proper system of water control for an area regardless of the type of vegetation that is to grow on it. The thing that most particularly limits the kind of crop you are going to plant is the fact that you know you can't raise crops not adaptable to this latitude and general climatic conditions. Insofar as your moisture condition is concerned you have got to stabilize the factors which balance that moisture for a particular crop. Unfortunately, the best stabilization of moisture in the soil (a reasonably low water table) brings about the alarm you cannot use organic land in that way, that it is inevitable it is just going down and down and down until you come to the zero plane. If this be true then there is no need for any 208 million dollar project to try to control the remaining resources and rebuild them. I don't believe that is true. I do believe, however, that Florida lacks one of the greatest factors and that is a reclamation law which will require a controlled handling of her fresh water resources. If it is left to the individual to do just as he wants to do and handle the water in any way that he may choose then no amount of scientific study is going to help what I regard as a very critical situation. Thank you.

MR. WALLIS:

Thank you very much, Horace. There are two things which give me complete confidence that there will be a solution to this and many other problems confronting this area. One of them is a certain group of people who never hesitate to give their full and unqualified support to such public causes whenever and wherever the occasion demands. We have several of that group here tonight. I would like to have them stand if for no more than to take a bow. We would love to hear from them if they have something they would like to contribute. The other factor that gives me so much encouragement is the so-called Brass Hats or Bureaucrats as Luther Jones affectionately calls them. After agreeing on the objectives of this program, that is, the program for water control and the conservation of our water and land resources, they may then have wide differences of opinion from that point on. So that which is scheduled to be done must be warmly defended against objections and criticisms, both pro and con. I don't think anything has been done lightly or will be done lightly or will be done without the need to plan and full criticism of those plans. Those whom I would like to have stand for a bow are Bob Creech. John Bollinger and Ralph Blank. They are all typical of the solid support this area and this program have had. The support they have given in the past will be called upon again in the future. It affords a large part of the confidence I have that this and other problems will be worked out. What have you got to contribute, Bob?

BOB CREECH:

Well, I am somewhat like Luke. I came in here on the 19th day of January 1919, in fact I was one of the first passengers on the Coast Line Railroad. My uncle met me with his mulemobile—we didn't have automobiles in those days, and no roads. I believed in this country then and I believe in it now.

I will give you a concrete example on one farm that I have operated for 30 years to prove that land will not subside if it is properly taken care of. On the other hand, I don't think that it would have been possible to do more damage if you had gone out with the intention of burglaring and dissipating and destroying property. There could be no more complete job than has been done in the Everglades since I have been there. I see very little regard for the future use of that land from the way many have been operating it in the past.

Consequently, I have been called a fool many times for many things that I have done, one of these being for planting a cover crop every year. It has cost me about

ten thousand dollars just to plant that cover crop to try to protect my soil, eliminate weeds and insects, keep land free from root knot and attempt to put back on that land every year as much plant material as is removed from it by oxidation; and I can give you concrete proof that I have actually done that for over a period of 30 years.

In 1905 M. D. Garrett, one of the men who made a survey of Lake Okeechobee, ran a level on Ritta Island. When that land was homesteaded elevation levels were run on the meander line at approximately the 17-foot elevation. I went over there in 1922 and was going to get rich in a hurry growing celery. We started off fine. Since 1927 that land has had a uniform water table—not one of these jump-up-and-down kind. We go over there in the fall and if we have to pump in or out we establish a uniform water table. We plow under those cover crops—we do not burn them off—we prepare those lands and hold a uniform water table during the entire life of that crop. Following the harvest the cover crop is again planted within a week or ten days. This has been carried on now for a long period of years. With another pumping station taking water off the low ground I now maintain the same water table all over the farm; not too high to drown my crops, but high enough to grow them. I tell you, gentlemen, that land is properly taken care of. And I say it is a fact because today on Ritta Island I've had less than six inches of subsidence in 30 years. I have owned the land now for 30 years, farmed it for 30 years and I know what I'm talking about. The meander line surveyed in 1905 with a 17-foot elevation today is 16½ feet.

I am not discouraged at all about the Everglades. I don't think we will need to be flooded. The main thing we need, and I have watched these operations over a period of more than 30 years—we need a uniform water table. And this can come about only through a much closer regulation of the water in the whole area, including Lake Okeechobee. Thank you.

MR. WALLIS:

Thank you, Bob. It now gives me very sincere pleasure to recognize Mr. John Bollinger who has certainly been a tower of strength at every turn in the development of this soil and water conservation program.

MR. BOLLINGER:

Mr. Chairman and distinguished visitors: I have been very much impressed by the opinions of the scientists and of the engineers to whom we have been listening. The land that I used to plow (up in Georgia) was greatly troubled by washing away. In recent years I have observed that they have devised a plan whereby they can protect that land against such washing and now they are producing more crops on it than they did at the time I used to plow. I firmly believe that the scientists and the engineers that we have here can certainly devise some plan whereby our valuable soil in southeast Florida can be preserved.

I well remember attending the meetings of the Soil Science Society in 1942 and 1943 when this question of soil oxidation and subsidence was of very great concern to us and extensively discussed. Now you have the scientists and Director Fifield of the Experiment Station here who can give you full and complete information on how to build up your soil like they did in the first land I used to plow. They can give you that technical information through the Experiment Station arm of the University of Florida, where some of the finest scientists in the world are to be found. You also have some of the finest engineers in the world here. You can combine the knowledge of these two groups and I submit to you, that approximately 50 years from now you will have built a new soil and it will continue to do what the Lord intended it to do and that is to feed the population. With such a combination of technical and scientific knowledge I have a profound and abiding confidence that exactly that can be done, that actually you can stop the subsidence and proceed to build your soil so that it can continue to feed the people.

It is a delight for me to be here again this evening at the Soil Science Society's meeting. I hope that I may be privileged to attend it regularly from here on out. I intend to stay in this part of the country and, of course, the backbone of this section is the productiveness of the soil. I am indeed happy to be here.

MR. WALLIS:

Thank you, John. We are also certainly honored tonight in having Director Fifield with us, and greatly appreciate the effort required for him to be present. We also greatly appreciate the interest he and the entire staff of the Experiment

Station and of the University have shown in our problems. I don't know if Director Fifield may care to make any remarks but I would like very much to have him stand so that those of you who don't know him will be able to recognize him when you see him. We also have another very good friend of this area, Col. Matthews, Chief Engineer of the Division of Water Survey and Research at Tallahassee. Last but not least from a point of service, I want to call on Ralph Blank, Manager of the Palm Beach County Resources Development Board.

RALPH BLANK:

Chairman Wallis, it would seem that the subject had been very fully covered. I just want to say that we owe a debt of gratitude to Lamar Johnson and Mr. Stephens who bring us this challenge. Though they have brought us a challenge, they have not discouraged us in any degree. I happened to be Chairman of Governor Caldwell's Water Conservation Committee in 1946. In the course of the State-wide conference held at Lakeland that year Governor Caldwell said that it is going to take some great disaster in order for us to get water control improvements on their way in Florida. This was almost a prophetic remark, because, in 1947 the fearful flood that came and which so greatly accelerated the flood control program because of its disastrous results seemed almost a fulfillment of his prophecy. And I believe that this treatise that has been prepared and discussed by these gentlemen is going to do the same thing for our soil conservation problem; its going to invoke the ingenuity not only of the scientist and of the engineer; it is also going to challenge each and everyone of us who have our all invested in the Everglades section of the state. We are indeed grateful to all these gentlemen for this thorough discussion of a highly important problem here this evening.

MR. WALLIS:

Does anyone have a question? Or a comment they would like to make from the floor? If not I'm going to call on Dr. Allison to (interruption) QUESTION FROM AUDIENCE (Bob Creech).

Since you are the head of the water control outfit, can you give us any idea why the sudden reversal on the thinking of the elevation of Lake Okeechobee. That is what a lot of us are vitally interested in.

MR. WALLIS:

Why Bob, I'll be glad to schedule a meeting on that at Belle Glade for a discussion of the studies that are under way and the alternate plan in mind. I think that it is a rather lengthy question to go into now since there is no change that has been decided upon there are a number of studies of the best way to accomplish the objectives of the program, which I think would be very much in order to discuss at a public meeting. If the Water Control Committee of the Resources Development Board may care to sponsor such a meeting I'll work with them at any time or place.

BOB CREECH:

I know this is not the place to bring up this subject. The only thing I have in mind is that since a lot of people here have been to other meetings previously with representatives of the Flood Control District I should like to have them take a note that in the event we have to raise the level of the Lake, we will have to redesign every pumping plant around the Lake at a tremendous cost. Now, gentlemen, you may not know what I'm talking about, so let me explain just this one little thing to you. This whole program was set up and based on the Lake having a 5 foot head of water; the entire set up of the whole drainage district was based on a maximum 5 foot head of water. We ran into this in 1947, there wasn't a single pump capable of handling the water. We are bucking an 8-foot head right now and our motors are burning up. Now they may have some engineering, or other good reason. You people are land owners, and I want you to know some angle of this has been brought up at every meeting, because I've been to every one.

The minute you go over a 5 foot head of water your motor is overloaded. Now this is a serious thing that I'm talking about and when it comes up for public discussion, I'm going to be there and I'm going to ask the full support of all citizens even if we have to go to Congress to prevent any such thing as this. I may be crazy, I'm just a dirt farmer, but you can't make me believe as your land goes down that it is necessary to pile the water higher and higher to make me do more seepage

pumping. When the first rain comes, the water table is gone and crops are drowned out and you can't pump it off.

MR. WALLIS:

Bob, let me point out one thing. The present limits in reference to the control of Lake Okeechobee are a 3-foot range, between elevations 14 and 17 on Okeechobee datum. It's been proven that Lake Okeechobee, with present facilities, can't be fully regulated at that narrow range. The current studies have determined the range in which it can be regulated with the expenditure of the amount of money that can be justified. The indications are that it's going to take nearer a 6-foot range; and study is under way to determine what that range will be. Elevations of 10 to 16 on the present sea level you use, would mean 17.4. However, let's say for the sake of argument, that isn't the final decision. There are months of study and field investigation before that will even be recommended to the District office, to the Division or to Washington. But let's say that a range of 10 to 16 becomes substituted for the present 14-17, the encouraging thing about that is there will be facilities provided to hold it within that top range and you know as well as I know that while 17 is the prescribed height you have had 14 more than you've had 17. So there isn't any cause for concern, because it just hasn't been possible to regulate the lake within those limits. If the upper limit should be set at 17.4 representing 16 on mean sea level it will be held within that range and you will be much better off than you have been. However, nothing has been done in connection with this program that has been kept secret. There has been no final decision, and if it is the pleasure of the people in the Lake area to be brought up to date on those studies and the alternates under consideration, that's their privilege and I'll be glad to arrange it. However, let's not get strung out on a question that would last till morning. Now, does anybody have a question or comment from the floor?

AUDIENCE:

Chairman Wallis, Mr. Johnson touched on the subject of what we need most to do. He said the most important thing is the earliest possible development of the organic soils within the agricultural area, but that in order to do this we need roads. I notice on the program that under item number 8 we were to learn something about those roads. I wonder if anyone here can tell us about them.

MR. WALLIS:

Unfortunately it seems that there is quite a conflict of other programs this evening and the gentlemen who were listed on the panel for this particular subject (Merrill P. Barber, Vero Beach, and Paul Rardin, Canal Point) could not be here.

MR. RAOUL:

Is there not something that we can do in the absence of these gentlemen even if it be only to prepare a carefully considered resolution setting forth the sentiments of those present regarding this question of roads?

MR. WALLIS:

Since the discussion of the principal subject of the evening seems to have been concluded I should like to turn the meeting back to Dr. Allison who can carry on from here.

DR. ALLISON:

Thank you Mr. Wallis for the splendid job you have done in leading the discussion. We are also indebted to you for the good help your office has extended in making a record of this discussion possible. This, of course, will permit its inclusion in the published Proceedings of the Society. Now with regard to the question that has been raised by Mr. Raoul regarding item 8 on the agenda, I am inclined to agree with him and with Mr. Johnson as to the importance of having a substantial Road System follow very closely upon and, in fact be fully integrated with the development of the proposed Water Control System. In fact such a relationship and requirement would seem to be of almost axiomatic simplicity. Is there any discussion of Mr. Raoul's suggestion regarding the desirability of a resolution on the subject?

LUTHER JONES:

Mr. Chairman, are you inviting a resolution about roads?

CHAIRMAN ALLISON:

Inasmuch as you are Chairman of the Resolutions Committee of the Society, Luther, it would seem that you should be able to operate in this connection with a considerable degree of freedom, especially since the need for such a resolution is actively under consideration.

MR. RAOUL:

Mr. Chairman, if in order, I'll make a motion. I don't know if any of these good people are going to ride on these roads we are talking about but I am sure they will support the idea in principle. I now move you, Mr. Chairman, that the Resolutions Committee be instructed and empowered to draw up and distribute a resolution requesting Federal, State and County authorities to look carefully into the feasibility of constructing a publicly maintained road on top of each dike to be built by the Central and Southern Florida Flood Control District wherever such roads will become a desirable and necessary part of a transportation system required for the development of this area South of Lake Okeechobee as shown on this planning map of Central and Southern Florida Flood Control District.

LUTHER JONES:

I second it.

CHAIRMAN:

Is there any discussion? Are you ready for the question?

CLARENCE BAILEY:

There is one more angle that I haven't heard discussed much tonight and that is cooperation between the County Commissioners and all of these flood control operations. I just want to touch on the development and maintenance of County Roads and water control ditches along two especially new developments. I'm referring to the Willard Smith road which was recently made to his development out there. There are, of course, several others. I went to Jake Boyd, the County Engineer, to find out what the plans were and he said the Board of County Commissioners of Palm Beach County are not interested in taking care of water control. Now it appears to me that if they are not, we don't need the roads. We need the water control as much as we do the road, the new roads in particular, and vice versa.

CHAIRMAN:

It would be my thought that the resolution under discussion will cover such a question as you have raised; at least I hope so.

MR. BAILEY:

That's the reason I wanted to bring it out. I would also like to ask what sort of distribution this resolution will have if and when drawn.

CHAIRMAN:

It will of course be published in the Proceedings of the Society. It's distribution otherwise will naturally be according to its content and according to those to whom it is decided to send it as incorporated within the body of the resolution. Such distribution cannot be made, of course, until after it has been published in the Proceedings. Does that answer your question, Mr. Bailey?

MR. BAILEY:

Yes, very satisfactorily.

CHAIRMAN:

Is there any further discussion of the resolution? Are you ready for the question?

AUDIENCE:

Question!

CHAIRMAN:

All in favor of the motion as outlined and moved by Mr. Raoul and seconded by Mr. Jones say "aye".

AUDIENCE:

Aye—Aye—Aye.

CHAIRMAN:

Contrary, the same sign.

AUDIENCE:

No sign.

CHAIRMAN:

The authorization of the resolution has been by unanimous vote. The chairman of the Resolutions Committee, to which are additionally appointed Mr. Harrison Raoul (Belle Glade), Mr. J. C. Stephens (West Palm Beach), and Mr. R. Y. Patterson (Clewiston), will gather his committee and prepare such a resolution as has been discussed here this evening. They will decide to whom it is to be addressed and to whom it is to be sent, the latter not to be accomplished until it has been published in the Proceedings of the Society which will be in Volume XI. All of this is within the convention of the Society's procedure in a matter of this nature.

LUTHER JONES:

This we shall be glad to do.

CHAIRMAN:

If there are no other questions relating back to the evening's discussion I will now turn the Chair back to Vice-President Wander who, I believe, will want to hold a very brief business meeting.

DR. WANDER:

A brief business meeting will be held immediately following the adjournment of the present discussion. It, too, will be an open meeting and all are welcome to stay who are interested in doing so. It will not be recorded. Before adjourning the present meeting I want to add my thanks to all who have taken part in this really interesting and important discussion of Soil and Water Conservation. The Panel Discussion is adjourned herewith. 10:45 P.M.

SYMPOSIUM: AGRONOMIC PHASES OF FIBER CROP PRODUCTION IN SOUTH FLORIDA

THE WORLD CRISIS IN OUR SOFT FIBER SUPPLY*

WALTER R. GUTHRIE **

I'm not used to making speeches, though this talk I'm going to give you this morning is not what you would exactly call a speech but just some remarks of a hard-boiled manufacturer. We try to deal in facts and we are usually pretty conservative in our thinking, though we have had quite a bit of experience with kenaf, that is, with the kenaf that so far has been available. With the thought that some of you folks might be interested in seeing a few of the finished products that we have put kenaf into, if you will come forward at the close of this meeting I shall be glad to show you these yarns and burlaps or I might pass them through the audience at that time so long as we get them back.

The United States Government became interested in kenaf back in 1941 and 1942 when the Japanese were invading the southern part of Asia and, for some time, the Japanese Navy was actually in control of the Bay of Bengal. At that time it looked very much as though the supply of soft fibers from the Far East was going to be shut off completely. Our government therefore became very much interested in a fiber that could take the place of jute at a time when they didn't know how long they would be without this important fiber if the above took place. So the United States Department of Agriculture started to investigate different kinds of fiber and finally decided that kenaf was the most suitable one to do the same kind of a job that jute had been doing. Now I don't know just what the thinking was on the part of the U. S. Department of Agriculture but they decided that kenaf was it. They thought that kenaf was most suitable for introduction into the western hemisphere. And from what I have been able to observe I think they chose very wisely. As a matter of fact, as one who has to use the raw material, I think they did a good job in deciding that kenaf is what they should push. And so, my interest in kenaf actually began when the United States government decided that kenaf had possibilities for the western hemisphere.

About that time they asked me to represent our industry on the Munitions Board. As you probably know, the Munitions Board is located in Washington, with headquarters in the Pentagon, and on that Board there are several sub-committees; a sub-committee for steel, for cotton, for electrical apparatus, and a number of others. One of those sub-committees is the one on fibers of which I am a member. And this sub-committee on fibers decided that it should investigate kenaf, the introduction and use of kenaf very thoroughly.

As a member of this sub-committee of the Munitions Board I took a trip to Florida and Cuba last fall, about a year ago this time. There I saw kenaf that seemed to me was growing very well indeed as far as

* This is a transcript of the purely extemporaneous discussion with which Mr. Guthrie opened the symposium.

** Vice President, The Lehigh Spinning Company, Allentown, Pa.

the production of the plant was concerned. I was pretty well satisfied that kenaf was suitable for Florida and certainly suitable for Cuba and some of the other off-shore countries in the Caribbean.

However, I came to a conclusion last fall that most of my competitors did not agree with me on, at that time, but I think since they have all pretty much come around to think the same way I do about it. I've decided that if kenaf is going to be practicable in the Western hemisphere that we had to get away from retting. In Pakistan, and India, where jute comes from, the production of the fiber is really a peasant industry, that is, each farmer will grow two or three or four acres and he is responsible for retting just this small quantity and that will really be his cash crop. He sells that jute for cash and in many cases that is the only cash income that peasant farmer has. The rest of his land is planted in rice and vegetables and one thing and another so that the development of this fiber production in Asia has been definitely along the lines of a peasant industry. Well, I was satisfied that if we were going to produce a fiber to replace jute in the western hemisphere it couldn't be done on such a peasant industry basis; in fact, it couldn't be done on a retting basis at all. So I advocated at that time that we look very closely into methods of extracting the fiber from the plant on a mechanical basis, either on a mechanical or chemical basis. In any event on some other basis than natural retting as is being done with jute in India.

I presume that most of you gentlemen know what I mean by retting. For the benefit of those who perhaps don't know what retting is, I can only say that you might call it rotting in a certain sense. That is, the stalks are cut down and put in tanks, in rivers or in overflow areas and allowed to remain immersed for from five to ten days depending upon the temperature of the water; sometimes longer. During this time a complex biological action takes place during which the micro-organisms in the water attack the imbedded gums in the fiber, soften them and make it possible to free the fiber from the layers of bark and wood. Because of all the hand labor involved in such a procedure I was quite sure, so far as the Western Hemisphere is concerned that retting was impractical. There just isn't enough cheap labor in this section of the world to ret fiber in this fashion as the cost of the method, under such conditions, would be tremendous. Likewise the lack of knowledge and skill in this sort of work on the part of the people in our part of the world would also prevent it from being a practical procedure for some time to come.

A year ago this time when I advocated that if we were to lick this problem it had to be done on the basis of devising a machine of some kind to extract the fiber from the stalk, I had many critics who thought that the finished product from kenaf would not be of sufficient quality to compete with jute. Well, I have some products here today, gentlemen, finished products, yarn, a carpet over there with kenaf backing, some rope, some burlap cloth. All of this has been made from mechanically decorticated kenaf. So the argument that we cannot apply mechanical decortication to the extraction of fiber from this plant is no longer a good one. For as you see it is now a fact that we can extract the fiber from the stalk and do it mechanically. However, there obviously is still some work to be done on this process. There are different ways of doing this job mechanically and I think we ought to have just as much competition in this as we possibly can because if we have competing studies and

methods of extracting this fiber from the stalk then the "best" method, for obvious reasons, is going to come out much more quickly than would otherwise be the case. It is probable that you people who go on the field trip tomorrow are going to see some kenaf fiber being extracted mechanically out at Belle Glade. This would be a very interesting experience for everyone who is interested in this crop.

After I made the statement last fall in Havana that I was pretty sure that this job could be licked if the fiber could be extracted mechanically one of the big sugar companies in Cuba asked me if my company would be willing to act as consultant for them on this matter of developing a mechanical method of extracting fiber from kenaf; and we have been acting in that capacity ever since. But that doesn't necessarily mean that what we've done and what we are going to do is going to be restricted to them alone. This kenaf business is too big for any one company or one individual to try to control. I'm very sure of that. And I am as satisfied today that we are going to work out the most economical and the best methods of extracting this fiber from the stalk in which it is grown.

However, what I want to talk to you folks about today, principally, is what kenaf is worth, because I think a lot of people are under a false impression right in this connection. As many of you know, the United States Government has a big kenaf seed production program under way at the present time. They have contracted with growers here in Florida and in Cuba to grow kenaf seed and it looks as though by the end of this year Uncle Sam is going to own something like 4 to 5 million pounds of this commodity so that there is going to be an abundant supply for the 1952 season. At the same time the U. S. Government also has offered growers contracts to pay as much as 30 cents per pound for any kenaf fiber that can be produced for them this year.

Now perhaps that's all right at the start. It gives the grower for this first year some incentive. They ought to do all right at 30 cents per pound but I want to discuss this point with you just a little bit. If you are really going to develop a kenaf industry in the Western Hemisphere, we've got to be able to market the fiber for a whole lot less than 30 cents a pound. In the final analysis its John Q. Public that decides what a thing is worth when the finished product is ready for the market. That is to say John Q. Public will be willing to pay a certain price for those products and that more or less determines what an article is worth. In other words, John Q. Public isn't going to pay a disproportionate amount to support a price of 30 cents a pound.

We are beginning to know a lot more about what our cost should be and I want to put my emphasis on that today because if you gentlemen can really get your costs down, and I think you can get them down, a tremendous market for kenaf can be developed in this country. This, of course, can only be if you gentlemen will be satisfied with a reasonable profit per acre and realize at all times that you've got competition, and you are going to continue to have competition from Pakistan and India, chiefly from Pakistan. You are also going to have competition from the paper people in the U. S. A. as they have done a marvelous job of introducing the use of paper for a lot of purposes where jute has previously been used.

The principal product that I manufacture is a jute yarn for the carpet industry. That yarn goes into the back of rugs, wool-faced rugs, rayon-

faced rugs—in fact in the back of most domestic carpet. As a result of recent trials we are finding that kenaf does make a very very excellent carpet yarn. I have a carpet here with a backing made out of kenaf that I would be very happy to show any of you who may be interested.

However, the big market where kenaf could be used in this country is in bags. The bag industry in the United States is a tremendous user today, or was a tremendous user of jute, but jute has been losing out in that field chiefly because it is so expensive. As a matter of fact cotton bags of a lighter construction are being widely used today where jute bags were formerly used. And the use of paper bags, laminated paper bags, as each of you know, has developed rapidly during the past few years for the same reason. Now all that tremendous field can be obtained for the use of kenaf if you gentlemen can see fit to mechanize your operations to get your costs down in a way that will still permit you to make a good profit.

Now I'm not saying you gentlemen shouldn't have a good profit. You should have a good profit because no business is any good unless everybody connected with the transaction is making a reasonable profit. Gentlemen, if you're willing to keep your profit down, if you're willing to say that seventy-five dollars an acre is a fair profit to make after all expenses are paid, and I think seventy-five dollars an acre is a pretty fair profit for you Florida farmers, if you're willing to say a seventy-five dollar an acre profit is acceptable to you and you're willing to get into production on that basis then I'm sure that there is a tremendous field available for kenaf.

It begins to look now, and I think this estimate is pretty generally accepted, that an acre of kenaf can produce about two thousand pounds of fiber. I think an acre of kenaf will easily produce two thousand pounds of fiber and I've heard since I've been down in Florida a day or two of the possibility of very much higher yields on the organic soils out in the Glades.

Well, now, it would seem about fifty dollars an acre ought to be a fair figure for preparing that land and seeding it. Most of you know what that operation is out there. You plow and harrow it to prepare the seedbed and then plant your kenaf with the grain drill or a rice drill. I've been talking with some farmers down here and they seem to think about fifty dollars an acre is a pretty fair figure for the cost of preparing the land and planting the kenaf. Well, on the basis of two thousand pounds per acre of finished product that only amounts to about 2½ cents per pound.

After the kenaf is grown of course it has to be harvested. And it looks now as though the most practical method is to convert those kenaf stalks into ribbons as close to the place where the kenaf was grown as possible. We now have some pretty good ideas of what that is going to cost. We think that it is going to cost well under a cent a pound to do that but let's put down a cent for the cost of ribboning. We're pretty sure it will be done for much less but let's be a little generous and put down a cent for ribboning. Well, that brings the cost, so far, up to three and one-half cents. Now we are pretty sure that the actual decorticating is going to be done for well under a cent a pound, that is to say the extraction of the fiber from the ribbon has got to be done for well under

a cent a pound; but let's be considerate and say a cent for fiber extraction. That brings you up to 4½ cents per pound.

Now, the chances are that you are going to eventually end up with mechanical drying in some form to dry this fiber after it comes out of your decorticator, and then you've got to bale it. So we put in another cent for that. Though it is going to be done also for well under a cent a pound, we'll give you the benefit of the doubt and say a cent for that. So it looks to me if, without putting any overhead or depreciation in, that cost is only up to about 5½ cents. Now let's put in about three cents per pound for overhead. I really think, and mind you, gentlemen, I'm not saying you're going to do that this year, but I'll bet you within a year or two, after you get all the rough spots worked out here in Florida that your actual cost for kenaf is not going to be far from 8½ cents a pound.

Now, if you'll be satisfied with a profit of, say seventy-five dollars an acre, which you can't get on most crops in the south, you could afford to sell fiber and make a good profit for about 12¼ cents a pound. Well, gentlemen, if you can do that, you've got some business on your hands, I'm quite sure of that. If you can turn over to the manufacturer who can convert this material into yarn and into cloth and sell it to him for 12¼ cents a pound, the possibilities of building up a tremendous industry based on kenaf are very very good.

So what I want to recommend to you who are interested in the production of this new crop is that you do everything within your power to mechanize this operation. Don't leave any stone unturned to completely mechanize the whole work. Then, rather than undertake to get a monopoly profit on this thing and make a big killing, if you're satisfied with, we'll say a seventy-five dollar per acre profit, I'm sure that we'll see the day come when there will be thousands and thousands of acres of kenaf planted right here in Florida.

Now I would prefer to answer any questions which any of you may have with which I may be able to help you. However, I'm going to close the more or less formal part of this talk by showing you some of the finished products what we have made out of the mechanically decorticated kenaf which we have been discussing.

* * * * *

First, in regard to this sample of Axminster carpet, about half the weight of this item is kenaf. My customers who buy yarn from me from which to make carpets, say kenaf yarn of this type is very, very satisfactory for this purpose.

I say the cheaper you can get jute or kenaf the more you can sell. In this field today, unfortunately, they are beginning to use a lot of paper in carpet. I don't know whether the women in the audience realize it or not but there are now being made an awful lot of carpets with paper backing. Paper in this form sells for 7½ cents under jute. Jute today sells for about 31 cents a pound, the finished yarn, that is. The manufacturer's cost of the finished yarn is approximately 7 to 12 cents per pound depending on the size of yarn you are talking about.

* * * * *

I don't want anyone to get the impression here today that this sample of rope is better than manila hemp. However, here is a rope for good

general service purposes. As a farm rope, kenaf makes a very excellent product in this field.

Now one of the properties that mechanically decorticated kenaf has which we have not known anything about until a short while ago is mildew resistance, that is, without any treatment. It's much more resistant to mildew than jute. In fact it is more resistant to mildew than untreated cotton. Thus it has this and some other porperties that we didn't expect to find. Therefore, I want to take this opportunity to repeat that if you can get the kenaf cost down to where it should be, and still make a good profit, then there would undoubtedly be a good market for something like this.

Apparently the reason this mechanically decorticated fiber is so resistant to mildew is that in retted fiber the micro-organisms in the retting water stay on in that fiber after it has dried. Then, when you introduce the fiber to a moist, warm exposure again these organisms go back to work on the fiber and continue to break it down and even destroy it. In view of the fact you folks really have plenty of mildew in this part of the country, at least during certain times of the year, this should be a pretty useful article in this section.

In answer to a question someone raised just a moment ago regarding the strength of kenaf, I would say that under equivalent conditions of processing, grading, and testing, it should be about the same; at least I wouldn't say at the moment that it is any stronger than jute.

* * * * *

I am particularly anxious to show you this fine sample of sand bag made from kenaf yarn for the Corps of Engineers. This organization is very much interested in this fiber for strategic reasons. The Quartermaster Corps also is very much interested for the same reason. As a result we have a lot of sand bags made out of kenaf now under test to see how they stand up under such natural conditions of exposure.

* * * * *

Here is a skein of yarn such as the bags were made of. We spun this in our plant at Allentown just a few days ago. It is as fine a sample of yarn as can be made out of kenaf, we believe. It wasn't but two or three months ago that we thought kenaf was a little harsh and a little coarser than jute. We didn't think it could be spun down quite as fine as this. We are finding out new things about kenaf every day and it now looks as though we are getting a type of fine jute yarn out of this fiber.

QUESTION FROM AUDIENCE:

Mr. Guthrie, how about the comparative losses in your spinning operations in handling kenaf versus jute.

MR. GUTHRIE:

Inasmuch as we haven't had too much experience with kenaf in spinning thousands of pounds as yet, I don't want to get way out on the end of a limb until we've had more experience with it. However, we believe that in the quantity handling of kenaf fiber we are going to find that the manufacturing losses will be less with decorticated kenaf than they are with retted jute. There is not so much of that liver dirt and foreign material of one kind and another in it because it is washed pretty well in the decorticator before it comes out and we start out with a much cleaner fiber than we do in the case of jute.

QUESTION:

Does it have to be sized; that is, for making rugs?

ANSWER:

The matter of sizing will largely depend on the type of rug you are making. If you are going to use it for velvet loom—for a back on a velvet loom you would probably size it. However, if you were going to use it for the filling of an Axminster loom you wouldn't have to size it. That carpet there (points to sample) is an Axminster type that was not sized. However, latex was put on the back of it after it was manufactured to prevent it from slipping on a polished floor.

QUESTION:

What is the principle source of kenaf fiber at the present time?

ANSWER:

Well, we hope to goodness that one principle place is right here in Florida. We are, of course, really just getting started on this angle of the problem. It looks to be as though the two chief sources of kenaf are going to be Cuba and Florida.

QUESTION:

Can you purchase only limited quantities of it now?

ANSWER:

That is right. Only limited quantities of this fiber are now available. We can import retted kenaf, of course, but I do not want retted kenaf. We want mechanically decorticated kenaf.

QUESTION:

Why?

ANSWER:

Well, it makes a much better product; it makes a superior product.

QUESTION:

Mr. Guthrie, have you checked Puerto Rico as a source of kenaf?

ANSWER:

Yes, Puerto Rico is also a possibility. I understand, however, that land is quite expensive in Puerto Rico. You know that you have some excellent good land down here in Florida for growing kenaf.

QUESTION:

What do the growers feel about $75.00 per acre profit?

ANSWER:

Well, of course, this is a brand new question. I am trying to sell you gentlemen on the idea of keeping your aim down to a reasonable profit per acre and building up volume in this enterprise. If you want to build up a real volume business on of this and are willing to keep that profit at a reasonable level you can surely do it.

QUESTION:

You don't want retted fiber do you?

ANSWER:

No. I'll say. But wait a minute, maybe I had better qualify that statement. If you do a very excellent job of retting, the decorticated fiber wouldn't be any stronger. However, with a retted fiber, you get far more variations. You get some fiber that is very poorly retted and is full of weak spots and you get some other fiber that is very well done and makes an excellent carpet but the average job on a mechanically decorticated fiber will be superior to the average job on retting. Do I make myself understood?

QUESTION:

I would like to know if growers would be willing to accept $75.00 an acre profit. I would like to ask what a grower does get for his crop.

ANSWER:

As mentioned earlier the whole question of production and market is a new one with no one having had very much experience with it. With regard to the "crop" I wonder if you mean your green stuff. While I am not an agriculturist I do like the idea of putting as much of that green material back into the ground as possible.

QUESTION:

How about the decorticating machine that cuts it in the field?

ANSWER:

I think that something could be worked out on that. Of course, this machine that Jack Dempsey has that he is using on ramie will decorticate kenaf. What we are trying to do now is to develop a much cheaper machine that will do as good a job as you can on a big machine. We have been mixed up in the development of a decorticating machine which will be under test in Cuba within 10 days or two weeks and I don't want to say right now that this is the machine but it is a lot closer than anything that I have seen before. What we are trying to develop is a decorticating machine which will sell for less than $5,000 that any farmer can use. It certainly is a fact that an expensive decorticating machine like Jack Dempsey's is a little bit of a stumbling block. We're going all out in getting a machine developed that will be under $5,000 that will do a satisfactory job. I don't want to get into the machine business. what I want is fiber at a reasonable price and it's got to be a mutually profitable deal. It has to be mutually profitable to the grower: it has to be mutually profitable to the manufacturer and in the final analysis, as I have said before, it is John Q. Public that decides what he will pay for things. If you want to make kenaf a luxury business then keep the price way up. However, you're not going to build up any volume. If you want to build volume on kenaf you have to really apply your ingenuity and get your cost down. If you do that I think that you have a marvelous future.

QUESTION:

Is the fiber that is left from a seed crop worth anything?

ANSWER:

It isn't any good for my purposes. However, some manufacturer making a low grade product might be able to use the fiber that is left after the seed crop is removed. I am not going so far as to say that it's not good for anything. It could be used for paper. There is one thing about this particular angle, however, and that is the price for raw material used for paper must be very low. If you get more than 2 or 3 cents per pound for raw material from the paper manufacturer you are doing well.

QUESTION:

Mr. Guthrie, on that paper question, we understand that there is a paper manufacturer in Miami who will pay $300.00 per ton.

ANSWER:

$300.00 a ton? How much is that a pound? Let's see, it's around 15 cents. Well, if you can get anybody to pay 15 cents for it that is swell. It's wonderful. You know, one time I heard a fellow say that you could make $600 00 an acre on kenaf down here. Now, that kind of talk doesn't do this business any good because it sounds too much like a gold mine. If this were true I would get out of the manufacturing business and away from its many headaches and into the business of growing kenaf.

QUESTION:

If you can buy jute for 15 cents a pound, how much will you pay for kenaf?

ANSWER:

I will pay you 15 cents a pound for kenaf. You see, kenaf has some properties that jute doesn't have that can be exploited. This matter of greatly increased resistance to mildew is something that can properly be exploited, if you know what I mean. Good salesmanship could sell a product made out of kenaf, particularly down in the southern part of this country where, at certain times of the year, you are bothered with mildew. In such a situation kenaf mechanically decorticated, would be a very useful product.

QUESTION:

Do you find that there are many grades of kenaf?

ANSWER:

Well, I must tell you that you are a little bit ahead of me. We are going to try to do a little kenaf grading this week right down here in Florida in an effort to set up some tentative grades, some commercial grades of kenaf fiber. I don't believe that there are going to be many grades of kenaf. It strikes me that with mechanical decortication maybe 3 or 4 grades might be sufficient. I can't possibly conceive of how there could be as many different grades of kenaf as there are of jute. However, this classification simply has just got to be developed. We can't have any hard and fast rules to begin with. At least that is my opinion. Are there any other questions?

QUESTION:

What about the cost of manufacturing the yarn?

ANSWER:

It all depends on what size yarn you are talking about. In other words, the finer yarns are more expensive to make than the coarser ones. So we can only talk specifically if you mention a particular kind of yarn.

QUESTION:

What is the relation of fiber grade to manufacturing cost?

ANSWER:

I would say that your manufacturing cost on most low grade fibers wouldn't be any lower; in some cases, it might be a little bit higher. If you are going to spin lower grade products your saving must come from the cost of the fiber. Many times when you try to spin a lower grade fiber you have a higher manufacturing cost because it doesn't run as well.

QUESTION:

What is the cost of a sugar bag and how does the kenaf fiber fit into its production?

ANSWER:

I am not sure, I think about 90 cents. However, I am not thinking about sugar bags. This kenaf fiber is going to have a much higher price and perhaps it is too good for sugar bags. Possibly you could make sugar bags out of some of the poorer grades, I don't know. I do know that the sugar bags made in Calcutta for Cuba today are from very, very low grade jute. Possibly you could make sugar bags out of the fiber from the seed crop that one gentleman was talking about here a while ago. That might be perfectly all right for this purpose. What I am anxious for you gentlemen to do, now we are talking to these growers in Florida, is to make a high quality of kenaf and put it into an equally high quality fabric.

The problem in Cuba regarding the sugar bags is a little bit different. I wasn't thinking in terms of Cuban sugar bags just now. If you could start off with your seed fiber and be willing to sell that for a lower price, maybe 5 or 6 cents a pound, then you could do something with the cheap sugar bag. However, I think the problem in Florida is how to produce a high quality fiber for which you can get the maximum price. Certainly I do not think the problem in Florida is to make a fiber that can be used only in sugar bags.

In concluding and in reply to some remarks that were not too audible I want to emphasize again that my main obective has been to disillusion you people who may need it. You can't make $600.00 an acre on kenaf and make an industry of it.

RAMIE PRODUCTION IN THE FLORIDA EVERGLADES

Charles C. Seale, Edward O. Gangstad, J. Frank Joyner and James B. Pate *

The fiber plant ramie, *Boehmeria nivea* (L.) Gaud., is of oriental origin and since early times had been grown in many countries of southeastern Asia. The largest area of production is in China, and the fiber is used mainly for making coarse fabrics.

It was not until about the middle of the nineteenth century that ramie became distributed in various parts of Europe. Africa and the Western Hemisphere for the production of fiber.

Ramie was introduced into the United States in 1855 and since that time has been grown experimentally in several of the southern states including Florida. Alabama. Louisiana. Texas and California. In 1943 the growing of ramie was initiated on a commercial scale in Florida. The variety *B. nivea* P. I. 87521 obtained from Japan was used for propagating the crop.

Figure 1.—Ramie observation plots in the fiber plant introduction nursery, Everglades Experiment Station, Belle Glade, Florida.

The plant is a herbaceous perennial and is a member of the Urticaceae or Nettle family. At maturity the stalks are 6 - 7 feet in height and about ½ inch in diameter. The fiber is located in the bast and possesses a high tensile strength, a characteristic that makes it valuable for specialized industrial use.

PRODUCTION AND USE OF FIBER

Under proper conditions of management ramie grows well on the peat soils of the Florida Everglades. However, it is sensitive to flooding and should be grown only where good water control facilities are available. The stand can be severely injured by flooding for 36 to 48 hours.

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Ramie is propagated from rhizome cuttings. Seed is not recommended for planting except for crop improvement through breeding and selection. Planting is done by mechanical methods in the spring or early summer in rows 4 feet apart with plants 1 foot in the row giving a stand of about 10,000 plants per acre. Planting material loses it viability very rapidly after preparation and should be kept damp and protected from exposure until ready for use.

Figure 2.—Field planting of the commercial variety of ramie, *B. nivea*, P. I. 87521.

Fertilizer is applied at the time of planting in bands between the rows. Subsequent applications are broadcast in the winter season over the standing growth.

Ramie is cultivated mainly for weed control several times after planting until a stand is established. Heavy infestations of broadleaf weeds, which may develop when the stand is reduced by injury from flooding or frost, can be controlled by the use of 2,4-D. The herbicidal treatment temporarily sets back the growth of the plant, but does not have a detrimental effect on the quality of the fiber.

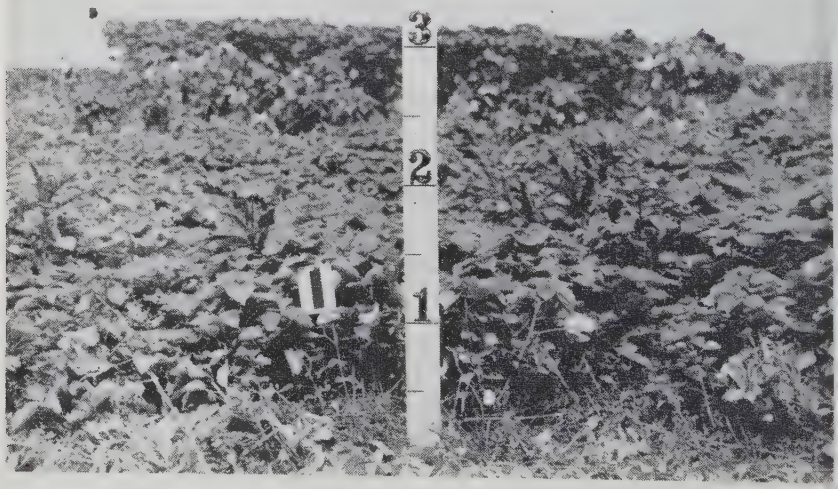

Figure 3.—Very poor growth of ramie in a plot receiving no potash, May 1952, second year of cropping newly cultivated Evergaldes peat soil, Canal Point, Florida.

The stand is generally ready for harvest the year after planting. The winter growth is cut back or "staged" in the early spring, and three cuttings are generally obtained in a season. The first crop matures in 70 to 80 days. In the summer when conditions of temperature and rainfall are more favorable for growth, the second and third crops are ready for harvest in about 60 days. So far no attempt has been made commercially to obtain more than three crops in a season.

Figure 4.—Normal growth of ramie in a plot receiving an application per acre of 60 pounds P_2O_5, 150 pounds of K_2O and the minor elements copper, manganese, zinc and boron.

After the sixth or seventh year of cropping a decline in yield may occur. In such cases it is generally profitable to rejuvenate growth by deep ploughing and cultivation.

A short time before harvest, ramie is defoliated by chemical treatment. The principal benefits of defoliation are (1) an increase in mill capacity and (2) the fertilizer value of the leaves. Recent experimental and large scale commercial test have shown that Endothal (3,6-endoxohexahydrophthalate) is effective as a defoliant.

Ramie is harvested, decorticated, dried and baled by modern mechanical methods.

Average yields of total green material and dry decorticated fiber for three crops in a season are 25-30 tons and 1,000 - 1,800 pounds respectively. In 1952 ramie fiber production in Florida amounted to a little under three million pounds of decorticated fiber from 2,500 acres.

Ramie fiber is used in the manufacture of automobile and furniture upholstery, linen-type fabrics, blends with wool, industrial packing, fire hose, fish nets and other miscellaneous articles.

EXPERIMENTAL STUDIES

A considerable amount of experimental work has been carried out on ramie by the Florida Agricultural Experiment Station in cooperation with the U. S. Department of Agriculture. The more important phases of this work are discussed.

Figure 5.—A close-up view of a ramie plant in bloom.

Since 1945 sixty ramie introductions have been obtained by the Everglades Experiment Station through the Division of Plant Exploration and Introduction of the U. S. Department of Agriculture and through other sources from several foreign countries, including Japan, Philippines, Indonesia, Cuba and Brazil. These introductions have been planted in the fiber nursery at the Everglades Experiment Station and the more promising types have been included in variety experiments.

During 1946-47 crosses were made with four ramie introductions of *B. nivea*, but the seedling obtained were destroyed by flooding. An unsuccessful attempt was made to cross *B. nivea* x *B. cylindrica*. The latter is commonly found growing wild in the Everglades and appears to be tolerant to high soil moisture conditions.

Figure 6.—Root system of ramie showing dense system of rhizomes and storage roots with typical shoot.

In contrast to the limited amount of work done on breeding, a considerable amount of attention has been given to the selection of improved types of ramie which possesses the following characteristics:

(1) a high fiber content of the stalk.
(2) a low green stalk: dry fiber ratio.
(3) a fine denier of fiber.

Some of the most promising selections possessing these characters have been included in variety experiments.

Preliminary trials conducted in 1947-48 indicated that several varieties of ramie *B. nivea* gave very much better yields on Everglades peat soil than on sandy soils in South Florida. Practically all of the varieties tested made very poor growth on Leon fine sand, but a few grew well on Davie mucky sand. More recent variety experiments on Everglades peat soil have shown that an introduction from Brazil *B. nivea* P. I. 205492 Murakami gave a significantly higher yield of fiber than the commercial variety. *B. nivea* P. I. 87521. In these experiments *B. Utilis* P. I. 205502 gave very poor yields.

In fertilizer experiments on newly cultivated Everglades peat soil, the greatest response in the yields of total green material and fiber was obtained from the application of potash and of the minor element zinc. On this type of soil nitrogen and phosphate had no significant effect on yield. On older cultivated Everglades peat soil, which had been cropped for four years with ramie and had received annual applications of potash, phosphate and minor elements. yields were significantly increased by the application of phosphate.

THE CULTURE OF KENAF IN SOUTH FLORIDA

E. O. Gangstad, C. C. Seale, J. B. Pate and J. F. Joyner *

Kenaf is not a new crop. It has been grown in tropical, subtropical and even temperate climates of the Far East for many centuries. Because hand methods have been required for the culture and processing of the crop, cultivation in the United States has been limited to experimental plantings. However, the potentialities for mechanical production of kenaf fiber have been recognized.

Preliminary trials have shown that the Salvadorian strains of kenaf are well adapted to the conditions of South Florida. Their vegetative vigor is particularly important for high yields of fiber. Manchurian strains ripen early and do not develop well under our conditions and are perhaps more suited to a temperate climate. Various tropical species which have been tested do not give a good yield of fiber. They are generally perennial in growth habit and are to be considered more as ornamentals.

TABLE 1.—Relation of Plant Development and Kenaf Fiber Yield to Four Different Ages of Growth at Five Different Dates of Planting on Everglades Peat, 1950 Season.

Planting Date	Measurements Taken	Age in Days at Time of Harvest			
		75	100	125	150
15 June	Plant Ht. (In.)*	70	87	115	116
	Stem Dia. (In.)**	8/16	8/16	9/16	10/16
	Fiber Content (%)†	4.41	6.83	6.36	6.33
30 June	Plant Ht. (In.)	73	94	107	111
	Stem Dia. (In.)	8/16	8/16	9/16	9/16
	Fiber Content (%)	5.23	6.31	6.64	6.72
15 July	Plant Ht. (In.)	69	87	96	98
	Stem Dia. (In.)	8/16	9/16	9/16	8/16
	Fiber Content (%)	4.89	5.67	5.46	5.49
30 July	Plant Ht. (In.)	60	68	73	75
	Stem Dia. (In.)	6/16	7/16	7/16	7/16
	Fiber Content (%)	4.05	4.71	4.74	.....
15 Aug.	Plant Ht. (In.)	58	62	63	67
	Stem Dia. (In.)	6/16	6/16	6/16	6/16
	Fiber Content (%)	4.16	3.89	4.21	.....

* From ground surface to tip.
** As measured at median height of plants.
† Oven dry basis after retting ribbons that had been separated by hand.

The commercial Salvadorian variety has given the best fiber yield, but has several limitations to commercial production. It is susceptible to root knot nematode, root rots and other diseases.

* See footnote page 129.

The Salvadorian strains of kenaf flower and fruit during October. The time of flowering is only slightly affected by date of planting. Vegetative growth is accentuated by planting in the spring. April through June, and a good fiber crop is produced. The vegetative growth of the plant is much reduced by planting in August and September (Table 1), and a smaller plant more readily handled for seed production is obtained. Plantings later than September have not given good yields of seed.

Kenaf is not as limited to a particular soil type or specific soil condition as many crops. In practice, the best seed crops have been obtained on the mineral soils, while the highest yields of fiber have been obtain on the organic soils. It is, in fact, difficult to obtain a good yield of seed on the organic soils. The light sandy soils are not very suitable for seed production because of severe leaching. Applications of fertilizer have in some cases been leached away before the plant has been able to utilize them.

TABLE 2.—Relation of Rate of Kenaf Seeding to Plant Stand and Fiber Yield from a Planting Made April 20, 1950, on Everglades Peat and Harvested at 118 Days of Age (August 16).

Stem Diameter* (Inches)	Plant Height (Inches)	Number of Plants (per A.)	Total Green Weight** (Lbs./A.)	Fiber Content† (Percent)	Fiber Yield (Lbs./A.)
Planted 7 inch row spacing, 10 pounds seed per acre					
¾ - 1¼	99	36,788	29,605	4.24	1,256
½ - ¾	87	32,451	10,144	4.20	431
¼ - ½	69	53,559	4,734	3.66	179
Total		122,307	44,483		1,866
Planted 7 inch row spacing, 20 pounds seed per acre					
¾ - 1¼	105	42,198	36,112	4.39	1,586
½ - ¾	90	37,329	10,956	4.66	510
¼ - ½	75	78,445	6,222	3.99	247
Total		157,972	53,290		2,343
Planted 7 inch row spacing, 70 pounds seed per acre					
¾ - 1¼	111	40,450	34,004	4.48	1,514
½ - ¾	102	61,341	19,225	4.58	873
¼ - ½	78	139,129	10,557	4.10	434
Total		240,920	63,786		2,820

* As measured at median height of plant.

** Of entire plant.

† Based on green weight plant material and oven dry fiber after retting ribbons that had been separated by hand.

For good yields, 1,000 to 2,000 pounds of 12-8-8 or 12-8-10 per acre are required on the sandy soils and 500 to 1,000 pounds per acre of 0-8-24 on the new muck soils and a similar amount of 0-8-16 for the older muck soils. The addition of copper is particularly important on the muck soils and has also shown some response on the sandy soils.

The seed may be planted with a standard grain drill using the common seven inch spacing. For fiber, a rate of 25 to 30 pounds per acre on the muck soils has given good results (Table 2). Such a rate of planting

TABLE 3.—Relation of Date of Planting and of Age at Time of Harvest to Green Weight of Component Parts of Kenaf Plants Grown on Everglades Peat, 1950 Season.

Planting Date	Plant Component	Age in Days at Time of Harvest			
		75	100	125	150
	Green weight in grams				
15 June	Total Plant	268.0	245.3	490.8	465.6
	Stem	169.7	194.2	404.5	375.6
	Ribbon	69.6	83.5	155.8	150.1
	Percent green weight				
	Leaves	24.4	20.8	17.6	19.3
	Shive	37.4	45.1	50.7	46.4
	Leaves and Shive	61.8	65.9	68.3	67.7
	Green weight in grams				
15 July	Total Plant	222.0	248.2	384.7	325.8
	Stem	150.3	206.0	290.2	269.1
	Ribbon	61.7	84.2	114.2	112.5
	Percent green weight				
	Leaves	32.3	17.0	24.6	17.4
	Shive	39.9	49.1	45.7	48.1
	Leaves and Shive	72.2	66.1	70.3	65.5
	Green weight in grams				
15 Aug.	Total Plant	88.7	112.2	94.3	.....
	Stem	67.5	74.9	76.7	.....
	Ribbon	24.1	28.1	26.8	.....
	Percent green weight				
	Leaves	23.9	33.2	18.7	.....
	Shive	48.9	41.7	52.9	.....
	Leaves and Shive	72.8	74.9	71.6	.....

will generally give 150,000 to 200,000 plants per acre or 4 to 5 plants per square foot. Higher rates of seeding will increase the number of small plants, but the number of plants satisfactory for fiber is not very much increased.

Kenaf should be harvested 100 to 125 days after planting. The percent yield of fiber increases rapidly up to about 100 days maturity. At 125 days the yield is near maximum. After 125 days, the plant soon becomes too mature for easy removal of the fiber, and the quality of the fiber deteriorates.

The best yields of fiber are obtained from the early plantings of kenaf, April through June. The height of the plant, and particularly the diameter of the stem is reduced in the later plantings.

A part of the cost of producing kenaf fiber is due to the large amount of green plant material that must be handled. Defoliation or topping has been advocated to reduce the amount of plant material which would be handled. In experimental plots it was found that the leaves account for 20 to 25 percent of the total green weight (Table 3).

Since the fiber of the kenaf plant is located in the outer portion of the stem, just beneath the bark, it is possible to further reduce the total green weight to be handled by mechanically ribboning the stalk in the field. The shive or inner portion of the stalk is found to account for 40 to 50 percent of the total green weight. If both leaves and shive are removed, 60 to 70 percent of the green weight will be left in the field.

The mechanical harvesting of the kenaf plant is facilitated by the use of topping devices to remove the upper portion of the stalk. Experimental studies (Table 4) have indicated that approximately 6 percent of the total fiber is lost by such a process, if the upper quarter section is removed. The basal portion of the plant contains the most fiber and the fiber yield is critically affected by cutting too high.

TABLE 4.—Total Green Weight in Grams per Section of Plant, the Percent Dry Fiber of Green Stalk Weight and the Percent of Total Fiber in Each Quarter Section, Base to Top, for a June Planting of Salvadorian Kenaf Grown on Everglades Peat, 1950.

Plant Component	Weight of Plant Sections (Grams)*			
	Base ¼ Section	Second ¼ Section	Third ¼ Section	Top ¼ Section
Leaves	.....	.....	.....	88.8
Stalk	136.0	77.9	51.5	26.2
Ribbon	44.4	31.6	18.1	6.8
Fiber**	7.7	5.7	3.1	1.0
Percent Fiber in Section**	6.8	7.4	6.0	3.9
Percent of Total Fiber in Plant**	43.8	32.8	17.7	5.7

* Based on total weight of green plant material.

** Based on oven dry weight of plant material and on oven dry weight of retted fiber from ribbons that had been separated by hand.

THE POTENTIALITIES OF SANSEVIERIA FOR FIBER PRODUCTION IN SOUTH FLORIDA

J. F. Joyner, J. B. Pate, E. O. Gangstad and C. C. Seale *

The more common cordage fibers, abaca, sisal and henequen are imported from the Philippines, East Indies, the Latin Americas and Africa. Although these fibers are standard articles of commerce and are readily obtained in the market during normal times, in the event of national emergency, foreign supplies, especially those from the Eastern Hemisphere, might be drastically reduced and the demand increased. For purposes of strategic defense, we need a plant suitable for hard cordage adapted to large scale mechanized production grown in or near the continental United States. As concluded by a group of specialists during the last war, sansevieria is one of the few hard cordage fiber plants which has potentialities for large scale mechanical production, and may possibly be grown in South Florida.

Original investigation of sansevieria in Florida was made by Dodge in 1892. He noted that the plant grew wild in the southern part of the State, as far north as Lake Worth on the East Coast and the Caloosahatchee River on the West Coast. Wild leaves measuring from 3 to 7 feet in length were obtained from Boca Chica Key and decorticated on a modified Finnegan-Zabrisky machine obtained from Paterson, New Jersey.

Various attempts were made to harvest the wild growth of sansevieria in Africa from 1900 to 1920. European colonists observed that the fiber was a natural resource which might be exploited. Although these attempts appeared successful at first, they were later discontinued at considerable financial loss. The round leaf species growing in these areas had a coarse, poor quality fiber and they did not recover well after cutting. It was soon necessary to go too far afield to gather new material.

From 1910 to 1940, several attempts were made to cultivate sansevieria in Mexico, Cuba, Puerto Rico, the Bahamas and the British West Indies. These efforts have not been very productive. At the present time, a limited amount of sansevieria fiber is produced in Mexico and imported by the United States.

During the last war, the USDA and the Everglades Experiment Station set up a cooperative project at Boynton, Florida, to develop practicable methods for culture, handling, harvesting and processing of sansevieria for fiber production. These investigations were continued after the war and plantings extended to Indiantown in 1950.

In the progress of these studies, it was found that the round leaf species, such as *S. ehrenbergii* Schweinf., the species commonly used for fiber in Africa, were unsuitable for commercial production because of poor fiber quality, slow rate of growth, low yield of fiber per acre and difficulty of reproduction.

The broad coriaceous leaf species such as *S. liberica* Ger. & Labr. and *S. longiflora* Sims have the highest fiber content. However, the fiber is not easily cleaned, the leaves are rather short and they are difficult to

* See footnote page 129.

propagate by leaf cuttings. They are, however, readily propagated by rhizomes and tend to have a seasonal growth habit.

The long or petiolar leaf species such as *S. thyrsiflora* Thunb. and *S. trifasciata* Prain. have shown the best promise for fiber production in Florida. They are readily propagated from leaf cuttings which can be planted in a large acreage by mechanical means. Under proper fertilization and adequate supply of moisture, they develop dense stands of plants and a high yield of fiber. While *S. thyrsiflora* has shown considerable damage by frost during the mid-winter season, *S. trifasciata* is somewhat resistant to frost injury. The broader leaf of *S. thyrsiflora* tends to sunburn more than *S. trifasciata*. In a cultivated stand, *S. trifasciata* generally grows somewhat taller and develops a more dense stand. It does not have as high fiber content as *S. thyrsiflora*, but has a higher yield of fiber.

Although sansevieria is commonly thought of as a xerophytic plant, capable of existing under arid conditions, good growth and yield of fiber is not possible without adequate moisture. If moisture supply is not adequate, the plant does not grow.

Proper weed control is also necessary until the stand is established. Weed competition will greatly retard or even prevent the development of a stand. Clean cultivation should be practiced until the plants begin to ratoon. Chemical methods of weed control are being carefully studied and are very promising. A new DuPont experimental weedicide, CMU, has shown very good results in the control of crab grass, water grass and Bermuda grass without injury to the sansevieria.

On the light sandy soils, a relatively high rate of fertilizer is necessary. One thousand pounds per acre of 12-8-8 fertilizer with minor elements and Uramon as a source of nitrogen have given good results. Nitrogen and potash appear to be the most limiting to growth. It also has been found that proper application of N and K increased the resistance of the plants to cold injury.

THE BREEDING OF IMPROVED VARIETIES OF KENAF, SANSEVIERIA AND RAMIE FOR SOUTH FLORIDA

J. B. Pate, J. F. Joyner, E. O. Gangstad and C. C. Seale *

There has been little research on the improvement of kenaf, sansevieria and ramie through plant breeding. High fiber yield per acre is a character of importance in all three crops. There are also special problems in each crop which can best be solved by breeding.

Variety tests on kenaf, *Hibiscus cannabinus* L., have shown that the Salvadorian strains are best yielding under Florida conditions. However, these strains are susceptible to root-knot nematodes, root rots and other diseases. The development of disease-resistant varieties is the major breeding problem in kenaf.

Several strains of *H. cannabinus* and related *Hibiscus* species were collected and planted in a breeding nursery in 1951 at the Everglades Experiment Station. A severe root-knot nematode infestation and various root rots developed in the nursery. An ornamental *Hibiscus* species was observed to be resistant to the root-knot nematodes and the root rots.

Pure line selection was initiated in the 1951 breeding nursery in the Salvadorian and certain other introductions of kenaf. This method of selection will lead to the development of homogeneous strains of kenaf. In the process of selection, particular attention will be given to disease resistance, plant type, fiber yield and quality of fiber. Crossing of various types of kenaf has already begun. Selection in segregating generations will give combinations of desirable characters present in the two original parents.

Several species of sansevieria have been used for fiber in various parts of the world. These species show variation in ease of propagation by leaf cuttings, rate of growth, length of leaves, resistance to cold injury, recovery after cutting, percent fiber and quality of fiber. *S. trifasciata* Prain appears to be more desirable for fiber production in South Florida than any of the other species. It can be readily propagated by leaf cuttings and recovers well after harvest. It grows faster than the other species and produces a very dense stand of plants with long leaves giving good yields. Though it can withstand frost injury better than the other species, an even more tolerant variety is desired. Other characters which should receive special attention in a breeding program are percent fiber and rate of growth. A small increase in percent fiber represents a substantial increase in yield per acre. Sansevieria is very slow growing and it may be possible to develop varieties with a faster rate of growth than *S. trifasciata.*

Clonal selection within species, seedling selection in *S. trifasciata* and interspecific crossing are breeding methods being followed in the sansevieria breeding program. Clones of different species, particularly *S. trifasciata, S. thyrsiflora* Thunb. (*S. guineensis* Willd.), *S. longiflora* Sims and *S. trifasciata* var. *laurentii* (DeWild.) N. E. Br. are being collected in Florida and obtained through the Division of Plant Exploration

* See footnote page 129.

and Introduction, U. S. Department of Agriculture. Clonal selection in a species which is propagated entirely by asexual means would not be expected to be effective unless somatic mutations have occurred. *S. thyrsiflora* does not produce seed and presumably has been propagated entirely asexually. *S. longiflora* and *S. trifasciata* var. *laurentii* produce very few seed and have probably been propagated mainly by asexual methods. Clonal selection in *S. trifasciata* offers the most promise of obtaining different types since it produces abundant seed. These have undoubtedly been spread by birds and other means. Clones of *S. trifasciata* in different localities may have originated from seed and be different genetically.

Since *S. trifasciata* produces seed, seedling selection offers promise in obtaining a cold resistant high yielding strain. At present, over 200 seedlings of *S. trifasciata* have been space planted in the field.

Interspecific crossing offers the possibility of combining desirable characters of two species. Several interspecific crosses involving *S. trifasciata*, *S. trifasciata* var. *laurentii*, *S. parva* N. E. Br., *S. thyrsiflora*, *S. longiflora*, *S. liberica* Ger. & Labr., *S. cylindrica* Boj. and *S. deserti* N. E. Br. have been made. Hybrids of *S. trifasciata* x *S. trifasciata* var. *laurentii*, *S. trifasciata* x *S. parva*, *S. trifasciata* x *S. liberica* and *S. trifasciata* x *S. deserti* have been obtained. *S. trifasciata*, the best natural species for fiber production in South Florida, has thus been crossed with the most cold tolerant type, *S. trifasciata* var. *laurentii*, and with the high fiber content species, *S. liberica*.

Factors in addition to higher yield which should be considered in a breeding program in ramie, *Boehmeria nivea* Gaud., are better quality fiber, particularly finer denier, and reduction in or elimination of seed production. Volunteer seedlings in a planting of a clone of ramie contribute to stand deterioration and may cause a reduction in the uniformity of quality of the fiber. A program of selection in ramie has been going on for some time at the Everglades Station. Early efforts to cross *Bohmeria cylindrica* (L) SW, a species growing wild in the Everglades, with the commercial variety of ramie, an introduction of *B. nivea*, to obtain plants more tolerant to flooding were unsuccessful. Clones arising from seedlings from the commercial variety of ramie and introduced clones are being evaluated. Some of these show considerable promise.

In addition to seedling selection in various varieties and selection among introduced clones, a method which appears worthy of trial is the production of a hybrid ramie. Inbred lines could be obtained by self-pollination. It will probably be necessary to self for 3 - 4 generations to obtain a reasonable degree of uniformity in the inbred lines. Once these pure lines are obtained, the best ones could be intercrossed and the hybrids tested. The hybrid could be propagated asexually and the vigor of the F_1 maintained.

THE OUTLOOK FOR A PILOT-PLANT SANSEVIERIA PROJECT IN SOUTH FLORIDA

FRED ABBOTT*

Members of the Soil Science Society of Florida and visitors. I find myself this morning somewhat in the position of the little man who had a vocation as an author and an avocation as a lawyer. He told many delightful little stories when with authors that mostly centered around lawyers; and about lawyers when with authors. He at one time remarked that when he was in the presence of lawyers they considered him an author and when he was with a group of authors they considered him a lawyer. And so it is with my position; when I am in a group of railroad men they think of me as a farmer and when I am with a group of farmers they think of me as a railroad man. In any event, a little review of the history of the sansevieria project in Florida might be in order.[1]

Early in World War II when the Japanese took over the Philippines they also gained possession of the great abaca plantations from which the nations of the world then largely secured their supply of marine cordage. The War Production Board immediately began to search for a substitute fiber and asked the Agricultural Department of the Seaboard to assist. We were familiar with the fiber that is recovered from sansevieria and were of the opinion that it would be a satisfactory substitute for abaca (Manila hemp). A quantity of sansevieria leaves harvested on the lower east coast of Florida from wild growth were sent by boat to Cuba for decortication in the sisal mill of International Harvester Company under our direction and at Seaboard expense. The fiber was returned to the American Manufacturing Company, Brooklyn, New York, who made it into ¾ inch rope and found that it compared very favorably with abaca; and was better than sisal. Sansevieria fiber also was found to be well adapted to the hard fiber machinery in use in America.

In 1942 the War Production Board, as a result of the above investigations initiated the setting up of the Research Laboratory at Boynton, Florida. This was to study the agronomic and mechanical problems of producing and processing sansevieria fiber. This work has been continued thru the years by the U.S.D.A. and the Florida Experiment Station on a gradually increasing scale until now it is felt that sufficient information has been developed to warrant the establishment of a semi-commercial plant.

Sansevieria was brought to the attention of Mr. George I. Dewey of the Bureau of Ships of the U. S. Navy. His reaction was that, in the interest of national security, it is what the navy needs as a source of marine cordage fiber located on the mainland of the U. S. where it would be available at any time and all times and grown where it would not displace food and feed crops. Sansevieria grown in certain areas of the lower east coast of Florida fully meets these requirements. Supplies of Florida-grown sansevieria fiber have been furnished the navy's ropewalk in Charlestown Navy Yard, Boston, Mass., several different times at the

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[1] Note: A picture of the crop in the field, the decorticator and the baled fiber is to be found in the photo series covering the field trip beginning on page 175.—Ed.

request of Mr. Dewey. At the conclusion of the last test run of 1,000 pounds Mr. Dewey prepared the necessary specifications for purchase of sansevieria fiber by the U. S. Navy as these tests had satisfactorily proven that sansevieria is a satisfactory alternate for abaca. Furthermore. it has been determined that commercial manufacturers are interested in almost unlimited quantities of this fiber. Thus the need for sansevieria fiber has been established both by advice of the armed services in the interest of national security and by those commercial interests who would like to buy this fiber.

The Navy's request of the Munitions Board for a supply of domestically produced sansevieria fiber has resulted in the issuance of a directive to the Secretary of Agriculture for a fiber plant operation. Such a project operating on a pilot plant scale will permit perfection of all phases of growing, harvesting and decortication on a commercial basis and, at the same time, provide a back-log of material and information that would permit the rapid expansion of the acreage in time of emergency. Both the people of the U. S. Department of Agriculture and the Florida State Experiment Station who have worked with this crop through the years are in accord with this pilot plant program, the establishment of which might mean a new industry both for the State of Florida and the United States and go far in avoiding the recurrence of finding ourselves without the necessary fiber supply for marine cordage as we did in World War II. Thank you.

CHAIRMAN:

Are there any questions?

QUESTION:

Why can we not use the abaca from the project that is being developed in Central America?

MR. ABBOTT:

Particularly because of sea transportation that is necessary in getting it to our manufacturing plants.

QUESTION:

Do we have enough foundation plant material to start such a project?

MR. ABBOTT:

Yes, at least in a small way.

QUESTION:

As you may know, there is quite a lot of it growing in various areas down on the Keys. Would this be useful?

MR. ABBOTT:

They won't necessarily use that variety.

QUESTION:

How about growing the crop on down in Central America—say in Costa Rica?[2]

[2] Unfortunately no one seems to have thought of bringing up the question of growing this fiber in frost-free Mexico with her joint boundary line of many hundreds of miles with the U. S. and where there are vast areas of eminently satisfactory land for the purpose. This of course should not minimize the need for working out the problems of mechanized harvesting and processing which, along with higher fiber yields per acre or per hectare, might give this fiber an appreciable advantage over abaca—at least within the field of its particular adaptability. Incidentally, the culture of sansevieria on a small scale has been under way for a number of years in Mexico.—Ed.

MR. ABBOTT:

Doctor (J. J. Ochse), that is what we were talking about. In World War II we wouldn't trust coastwise shipping to get fiber over here as we had 10 to 20 boats a week sunk off the coast of Florida. The Navy wants to get production started in this country. It is true they are developing abaca in Central America and if we could get it here with assurance at all times it would be that much better. However, as I see it we must face the facts and develop a backlog of domestic hard fiber production just as soon as possible.

CHAIRMAN:

Are there any other questions? . . . If not I would like to ask Mr. James M. Dempsey, Manager, Fiber Division, Newport Industries, Inc., if he will lead the discussion.

MR. DEMPSEY:

I was very much impressed by some of the points which were brought out by Mr. Seale and would like to comment on a few of them.[3] First of all is the question of pest control. One kind of insect that we have not been able to control very well is the wire worms that attack the roots of the young plantings. That is one problem which is in need of a little more work.

In my opinion, the work that has been done on fertilization has been most thorough during the past several years. However, the problem of rehabilitation of old plantings is one concerning which we don't know too much. We have done a little work on it and it has been encouraging so far but that is another problem which very definitely must have more work done on it. I know it's pretty close to lunch time but I'll be very glad to do what ever I can with any questions that you may want to raise. However, it would seem that most of the questions on kenaf have already been pretty well covered by Mr. Guthrie and others.

MR. EDWARDS:

I would like to make a remark or two about the various fiber crops being worked on in this area. We have heard a lot of discussion here about the growing and processing of these crops for fiber. There is one thing that hasn't been touched upon at all and that is the various by-products that can be had from these plants. I have analyzed ramie and found that the plant contains gums, waxes, chlorophyll and many other components of potential value if they could be recovered economically. For instance the woody stem is 85 percent pure cellulose which could be used in plastics and in many other ways. In my opinion the by-products of some of our fiber plants could be made to more than pay the whole cost of production. It seems to me that the time has now arrived when we should pay some attention to at least some of the many by-products that could be recovered during the processing of these plants.

MR. DEMPSEY:

From the standpoint of by-products that may be derived from ramie my company hasn't been exactly idle. However, the emphasis very definitely has been put on the recovery of the fiber. It is quite true that there is considerable work that should be done on recovery of other products. In fact, some years ago, when we first started our operations, we started in dehydrating and making a leaf-meal from the tops as was referred to by Mr. Seale. For several years we sold that meal primarily for the extraction of chlorophyll; also as a feed. Insofar as the economics of the operation was concerned, we ran into the problem of high moistures that had to be taken out of the plant. When we finished it was not too profitable because the end product which we sold had to compete with alfalfa leaf-meal; and we also learned that by defoliating in the field before harvesting we could leave about 40 percent of the total green weight of the plant material in the field. This not only added to the nutrient substance, in the form of this crude plant material that it was possible and desirable to leave in the field, but it also gave us an entirely new outlook in the decortication process in view of the greatly reduced amount of plant material that it was necessary to put thru the plant. There are, of course, possi-

[3] Note: Many of the field and mechanical problems referred to in the earlier papers and in the discussion that follows are to be found quite well illustrated in the photo series covering the field trip beginning on page 175.—Ed.

bilities of utilizing the woody material or shives after decortication. However, the best use we know for it at the present is as a compost which when well decomposed makes quite a good organic fertilizer analyzing somewhere in the neighborhood of 4 percent nitrogen, 2 percent phosphate and 2 percent potash. It is especially good as an organic nitrogen for sandy soils. On the peat soil such as we have I don't think that it would be particularly helpful.

QUESTION:

What is the principal use of ramie at the present time?

MR. DEMPSEY:

Prior to 1951 our fiber was largely sold for export where it was used in quite a diversified number of fabrics such as table cloths, towels, sheets; also sewing threads and many other items. It was largely sold to France, Switzerland, Germany and Italy. It also was used in such industrial fabrics as canvas, fire hose, etc. It also was blended with wool in quite an effective manner or was spun by itself for knitting yarns, etc. Those were some of the principal uses before this year. We have since put in a degumming plant which is now in operation. A goodly portion of our production is going to be used domestically from now on. We hope that more and more of it each year will go into a number of diversified products. So far, however, it has largely gone into industrial types of material such as have already been mentioned.

QUESTION:

Does ramie blend well with other fibers?

ANSWER:

It seems to blend with other fibers very effectively. It has certain characteristics that are unique. Particularly in the case of blending with wool it not only adds to the strength of the finished yarn or fabric but also substantially reduces stretch and shrinkage for which all wollen materials are quite well known. We now so definitely believe ramie will be able to find its own place that I would not like to compare it with other fibers or fabrics because of certain characteristics which it has that makes it most unique in a wide field of adaptability.

QUESTION:

Are there many different varieties of ramie and in what way do they vary?

ANSWER:

I believe that most of those types mentioned by Mr. Seale were primarily from seedlings, were they not?

MR. SEALE:

That is correct. We have received for study thru the Division of Plant Exploration and Introduction in Washington small lots of true seeds from a total of 12 varieties of ramie from Indonesia (Java) from which many of them were developed.

MR. DEMPSEY:

We received cuttings of three varieties of ramie that came in at about the same time. These were: Poejong, class 1; Djawa Timoer; and Lembang. Unfortunately the first one germinated only very poorly and we lost it. Insofar as the other two types are concerned, our observation on the peat soils are that the plants do not grow as tall as our standard variety and we have not found that they have a fiber content that is anything to become excited about. However, some of the seedlings that Mr. Seale has been working with certainly show some promise from a selection standpoint.

MR. SEALE:

In addition to the materials from Indonesia already referred to we also have received cuttings of 8 or 9 varieties from the Philippines, some from Brazil and Mexico and two quite interesting types from Japan, namely Saikeiseishin and Kagasei. These latter two, of course, were particularly to assist in our search for a variety with a finer denier than that we now have in general culture.

QUESTION:

What is the principle problem of maintenance in a perennial crop of this nature in its handling from year to year?

MR. DEMPSEY:

The growth of the crop definitely declines as the planting grows older. However, we have only observed seven complete years of growth on peat soils. Generally speaking, after the third year, there is a decline in height of the plant. The roots become more matted, the old plants die off and new ones came along. The stalks also are generally smaller in diameter. Surprisingly enough, however, after the third year, it seems that the stems become easier to decorticate and consequently the fiber recovery is greater. Unfortunately, however, the plants of these older stands seem to have less vitality, consequently if you have a cold winter, like we had last year, there is a tendency towards the production of an inferior first cutting due to losses from the cold and the time required to reestablish the stand.

QUESTION:

Have you tried to rejuvenate an old field?

MR. DEMPSEY:

We studied several methods on a small scale before we decided to try a rehabilitation job on 300 acres. That planting was six years of age and was done last fall. It consisted first of turning the soil fairly deep with a plow, disking, and then leveling. Unfortunately that was done late in the year and we had a number of frosts at the most inopportune times during the winter that followed. Every time the new sprouts would come up they would be knocked down again by the cold. Consequently, we had a very poor first crop. However, the second cutting was quite comparable to a new planting, that is, when you have large, tall stalks that are harder to decorticate and somewhat lower in fiber yield. Unfortunately that was some of the last of our third harvest this year so it will be too late to harvest it a third time. As you can see we don't know too much about the rehabilitation of aging ramie plantings at this time.

QUESTION:

Are there any processors in the United States using your fiber at the present time?

MR. DEMPSEY:

Yes, there are several. Those buying our fiber in any quantity at the present time are using it largely for upholstery and other durable fabrics of this nature. This is as blends for the most part, however, because our limited production wouldn't warrant making up too much yardage of cloth from 100 percent ramie. Furthermore, we have other markets such as are to be found in the packing industries (as in stern tubes on ships) and numerous other novel uses for which we also want to reserve some tonnage. Our domestic market wants only degummed fiber. This, of course, is quite the opposite of the foreign mills. They apparently want to degum the fiber to their own specifications for the type of spinning they use it for.

CHAIRMAN:

Are there any other questions? . . . If not I should like to ask that you return promptly for the afternoon meeting which is to take up the engineering phases of the fiber work beginning promptly at 1:30 o'clock. The meeting is adjourned.

SYMPOSIUM: MECHANICAL AND CHEMICAL ENGINEERING PHASES OF FIBER CROP HARVESTING AND PROCESSING IN SOUTH FLORIDA

A PICTORIAL REVIEW OF PROGRESS OF THE ENGINEERING PHASES TO DATE

Mills H. Byrom*

I think the talk already given and the discussion that followed have brought out clearly the part that sansevieria may play in the event of another emergency for our armed forces. The other fibers, ramie and kenaf, may be equally important. Before we turn to the pictures, I should like to say a few words about the area that may be affected and something of the effect on the economy of our nation and our particular community if the full scale fiber production industry which we have every right to expect, becomes a reality.

A number of conferences with people in our defense agencies reveal that they are interested in a fiber that might serve for marine cordage in place of abaca. The abaca project in Central America has bolstered our needs to some extent and the Philippines are continually increasing their production, but with all of this, the supply is still far below the need for hard fibers. To make the shortage more critical, the British have severely curtailed the shipment of sisal to this country. Sisal, a cheaper fiber than abaca, meets a definite need in our economy, and with reduced supplies, our manufacturers are sorely in need of something to take its place. They tell us that sansevieria is an excellent alternate for abaca for marine cordage and that it is a superior alternate for sisal. There are a number of products for which sansevieria is particularly well fitted and it will be used in their manufacture as long as it can be obtained in satisfactory quantity and quality. The center core of steel cables is one of these. There are perhaps other. Certainly, once production is started, the fiber will find a niche all its own as Mr. Dempsey was telling us this morning that ramie would do.

The manufacturers and defense agencies who have been consulted, have indicated that they would like to have at least 50 million pounds of sansevieria available on the market in the United States right now. If 2,000 pounds of dry fiber could be raised on an acre it would take 25,000 acres of land to meet the requirements. Even though the fiber situation has materially improved during the years since the war, the improvement has been slow and the situation is still far from satisfactory.

A similar shortage exists with other fibers. We use somthing like 180 million pounds of jute annually in the manufacture of carpet yarns, linoleum backing, insulation for electric wiring, and many other items. Until recently, we have produced no woven goods or bagging from jute in this country. We have taken advantage of the 3 cent labor that is avail-

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able in the Orient and are using it to produce jute fabrics needed rather than to produce them with high priced labor at home. Through the years there has been only one jute weaving mill in the United States. It was located at the Federal prison at San Quinten, California. During a riot at the prison, the mill was burned to the ground, leaving not a single plant that can weave burlap or jute bagging of any kind. I understand from what Mr. Guthrie said this morning that his company has put in a few looms and that others are contemplating the installation of weaving equipment.

Some of the largest users of jute in the United States have told us that regardless of the jute situation in India, they would be glad to use up to half of their total fiber requirements in kenaf produced in the Western Hemisphere in order to establish an industry in this part of the world. We are interested in seeing as much as possible of that industry located in South Florida. Eighty to ninety million pounds of kenaf produced annually would require 50 to 60 thousand acres of land. Kenaf is unlike sansevieria in that it is an annual, grown from seed each year, and since its maturity period is relatively short, 100 days, it can be grown over a wide area in the South. Most of the State Experiment Stations in the Southern states have tried plantings and find that it grows well. We have decorticated samples from several states and find the fiber yield and quality to be good.

The possible needs, present and future, for ramie fiber have been brought out clearly this morning. However, I should like to call attention to the fact that the potential need might mean a much larger demand for fiber than that which can be grown on Everglades soils.

The establishment of a long vegetable fiber industry in this country appears to be confronted with insurmountable problems. The manufacturer cannot tool up his facotory and train workers to fabricate a certain fiber unless he is assured an uninterrupted supply. Likewise the farmer cannot afford to grow it unless he is assured a market at a fair price. At times it appears very difficult to overcome these problems of supply and demand.

The picture we have to show you today is not of any one accomplishment of our research, but is rather a history of the development of fiber processes as they have taken place in South Florida. A great deal of the work on ramie comes from the development of Newport Industries as well as from our own research.

The presentation of the film with a running discussion of its principal features by Mr. Byron followed. Some of the equipment shown in the film, especially the binder and ribboners, including the big decorticator, will be found in the photo series reviewing the field trip beginning on page 175.—Ed.

THE PRESENT NEED FOR A SUITABLE RAMIE AND KENAF HARVESTER AND SOME ADVANTAGES OF LIMITED FIELD PROCESSING

JOHN W. RANDOLPH *

Factors now influencing the bast fiber market indicate full justification for the expansion of ramie and kenaf production in Southern Florida and elsewhere in tropical and sub-tropical areas where soil and climatic conditions are suitable. However, trade practices and accepted standards within the textile industry seem to place unusually specific requirements on any material that is offered as an alternate to those that have been in use for many years. This, of course, has particular reference to any effort at substituting kenaf for jute.

Much of the history of bast fibers, insofar as harvesting, processing, and the development of a commercial package is concerned, has been based on hand operations which provided those special skills needed to retain the distinctive qualities of these long fibers. The ultimate arrangement of such fibers in the finest textile products has a close correlation to the pattern worked out by nature in a bast fiber crop where long, undamaged filaments are arranged in a system of true parallelism. For many years some foreign countries have had an abundance of low-cost labor which, under the open market conditions that have prevailed, virtually has given them a monopoly as producers of this type of fiber.

Products of low grade and relatively high cost have been a definite setback to several recent large scale attempts to use available methods of harvesting and processing to build up a new source of supply. This statement should not be accepted as final, however, because these conditions of production have many ramifications in which each seems to have definite opportunities for significant improvement.

The present discussion is limited largely to the harvesting operation especially to the extent it might find a coordinated place in any large scale culture of ramie and kenaf up to the stage of final agricultural processing. A review of past harvester development, a limited examination of the applicable requirements of the textile industry, and an analysis of a bast fiber crop's harvesting problems must all be considered in the development of suitable methods of harvesting for any definite system of processing that is to follow either in the field or in a centralized plant to which, in the latter event, such a great mass of plant material must be transported.

PRESENT SITUATION IN THE HARVESTING OPERATION

The harvesting of ramie and kenaf in South Florida is now carried out with a hybrid John Deere and International hemp binder of war-time vintage. This machine was described in the joint report to the Department of Commerce (1948), "Ramie Production in Florida," as having the following service value:

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"The growing characteristics of ramie present many harvesting problems. The top 12 to 18 inches of plant contain a dense growth of large, hairy leaves which are entwined and tangled before harvest and become more so as the stalks are cut and carried to the tying mechanism. This results in a poorly shaped bundle. To avoid loss in decortication, the bundles must be uniformly butted and the stalks straight and untangled. Due to a combination of plant characteristics and limitations of the machine, a bundle of this quality is not produced. A variation as great as 18 inches in the butting of the stalks is found and many are bent and folded at the tie. Further deterioration in the condition of the bundle takes place each time it is handled in bringing it to the decorticator."

The same report, if it were to cover the kenaf harvesting operations which have entered the field since that time, would have to include an even more drastic series of troubles and to credit the equipment with still larger fiber losses as reflected in both quality and quantity of the final product. Furthermore, if the report were brought up to date in this respect it could give no added improvements in this basic harvester and would have to indicate that the troubles and costs of repairs are actually increasing on this mechanical orphan of World War II.

However, this old hemp binder, as used in the Everglades for the harvesting of these bast fiber crops, is still deserving of much credit because it has helped the development of two large commercial operations. These organizations will give particular credit to their shop and field men who have rendered such excellent mechanical services and have made many modifications to give the machine strength where needed. These men and others have developed many forms of attachments or design changes to improve the work of the binder just as much as possible. The efforts at topping and general improvement in the crop bundle, as produced, were short lived because of the structural and other limitations in the original machine. The bundle carrier designed and built by Newport Industries, Inc., has particular merit because it does a good job, saves much labor, and places no additional load on the binder. This implement, with bundle carrier attached and numerous other mechanical appliances can be seen in the series of photos covering the field trip beginning on page 175.

Chemical defoliation of the ramie crop before harvesting also has many advantages and it is now the accepted practice by Newport Industries, Inc., after having been greatly reduced in cost and increased in effectiveness by many careful trials of rates, materials and timing.

The Importance of Careful Harvesting and Early Handling of Bast Fibers to Insure Favorable Conditions in Which They Arrive at the Mill

Commercial grades for bast fibers include many major considerations in preparation and conditioning in determining these placements. This, in substance, means that all mechanical operations leading up to the final commercial package, the bale, must give the fullest possible consideration to the preservation of maximum parallelism in the fibers as produced by nature. Top values are always received for a full-length

product which has not been subjected to detrimental treatments that have tended to appreciably tangle or alter its natural arrangement.

The need for care and precision in all handling operations involving the raw fiber is well justified by an understanding of the preliminary operations within a spinning mill. It is exceedingly important to understand that any detrimental treatments within a series of mechanical operations that might tend to tangle the fiber can seldom be corrected without increased costs being forced on the successive operations. All fiber abuses will in some way modify the final result. Many practical considerations prevent the development of a continuous series of closely coordinated processing operations between the farm and the fiber industry. Such interruptions take the form of drying, packing, storing, and long distance transportation operations that also can cause disorder and increase the spinning mill's cost.

The "strick", also called "hand", is the true physical unit in the bast fiber exchange between the producer and industry. These small units of fiber, used in the buildup of the commercial bale, are given values on the basis of their quality, preparation, and condition before they were placed in the bale. These values are further modified by the methods used in packing the bale and related conditions.

The spinner desires that each strick will be representative of the whole lot and it should be made up of a fairly uniform quantity of clean, full-length fibers, fully parallel, and evenly butted. There are marked price penalties for tangled lots with matted, criss-cross snarls, nappy fibrous balls, reverse loops, and knots. In fact, a "helter-skelter" arrangement of damaged bast fibers may force a "tow" classification.

The spinner's specifications are in part based on the conditions associated with the buildup of the sliver. This operation, for full length bast fibers, is a slow hand process and it must be carried out with skilled labor. The complexity of the sliver buildup is reduced when each strick in a bale is so packed as to retain its original identity and natural quality. These requirements, translated into action, means that when the strick is correctly opened and grasped by the worker, it can be fanned out by a swing motion into an open, parallel pattern of fiber alignment so that it can be deposited on the "spread board" as required in the completed action obtained with one grasping.

The real art of the sliver buildup is in the maintenance of an exact pattern in adding strick after strick, with the butts in one direction, working out a continuous series of overlaps to anticipate the required density and uniformity of the forthcoming sliver. The spread-board, when loaded with a sliver, serves as the feeder to the first mechanical unit in a spinning mill.

Some mills are quite tolerant as to the amount of plant waste that may be contained in bast fibers. However, they make a major distinction between "free", "embedded", and "firmly attached" wastes. Fibers that have been so processed as to retain much of their natural parallelism and are undamaged otherwise will normally give up "free" waste products in the first operations of a spinning mill. "Imbedded" and "firmly attached" wastes combined with broken and damaged fibers are bound to cause large mill losses.

The somewhat pessimistic facts that have been cited on the primary mechanical processing of bast fiber crops should not be considered dis-

couraging, because they involve relatively recent agricultural introductions of suitable varieties of ramie and kenaf. Instead, one should consider the time and the associated costs required to develop such a complicated machine as an effective cotton picker and many other highly specialized harvesting and processing machines for crops that have been grown on vast acreages in this country from the very start of its colonization.

Stapled Bast Fibers

The ideal requirements essential to the proper farm handling of bast fibers have been minimized by the advocates for stapled ramie fibers which can be used in many textile mills. However, this raw fiber market has it's specific requirements that favor exact uniformity in length of staple without other forms of deterioration. Hence, up to the point of cutting the fibers, all preliminary operations represent no real chance for a compromise in the optimum requirements of harvesting and field processing.

Weight Distribution of Kenaf Crop Among the Component Parts of the Plant with Application to Problems of Harvesting

Gangstad, Seale, Pate, and Joyner in their report on "The Culture of Kenaf in South Florida" which appears in this Proceedings, gave production data for three rates of seeding (Table 2). The average of the three green weight yields reported by these authors has been given a graphic distribution analysis by the use of their sectionalized plant data (Table 4) and other information. Figure 1 shows a graphic weight distribution of leaves and stalks for plants of three different sizes. This height-weight analysis has much significance in connection with methods of harvesting and field ribboning or decortication in which numbers of stalks or size of bundles is used to regulate the operations. As an application of same, let us assume that an in-line field ribboner can handle 7 stalks per unit feeding for the 1¼ to ¾ inch butt diameter group, 7 stalks of the ¾ to ½ group, and 14 stalks ranging from ½ to ¼ inch. Each group will give approximately full coverage over the face of an 18 inch drum. Also let us assume that the feeding and fiber recovery operations (number of men required not part of this report) could be maintained at 20 per minute, the machine's working capacity in terms of pounds of dry fiber per hour is given in Table 1.

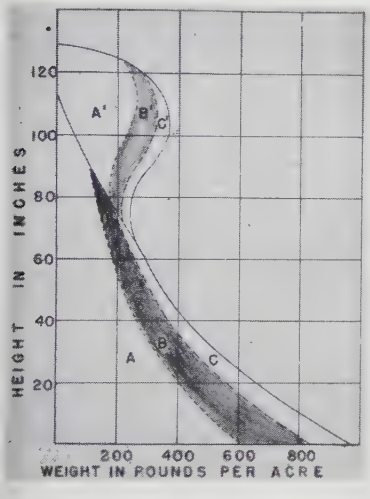
TABLE 1.—Influence of Size of Kenaf Stems on Rate of Ribboning with Hand Fed Machine.

Range in Stalk Butt Diameter (In.)	1¼ to ¾	¾ to ½	½ to ¼
Dry Fiber per Hour (Lbs.)	175	116	53

Considering the average acre yield as a unit and taking into account feeding adjustments whereby the above assumed rates can be duplicated, it would require 18.9 machine hours to process the fiber from the given acre and the rate of fiber production would be 124 pounds per hour. In actual practice, the overall result might favor discarding the very

smallest canes because the conditions under which they have grown have made the canes soft and tough and clean ribbons cannot be produced from them.

The data shown in Figure 1 has been shifted to a central axis in Figure 2, where the outside outline represents the total makeup of the entire crop on the average acre of kenaf cited above. Attention is called to the fact that the center of gravity of this average crop occurs at 49.97 inches above the base or at about the mid-section elevation. This is important insofar as the action of a reel on a harvester-binder is concrened. In contrast, consider that of a small grain crop where the weight balance is relatively high at crop maturity when a heavy grain head is supported on a light dry straw.



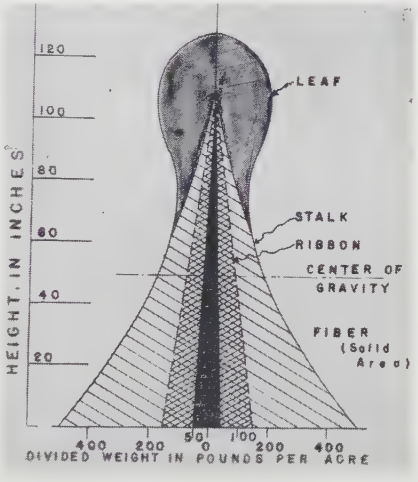


Figure 1 (left). Vertical distribution of green weight in a kenaf crop, leaves and stalks (53,853 lbs. per A.) shown in three stalk sizes ranged as follows: A, ¾ in. to 1¼ in.; B, ¼ in. to ¾ in., and C, ¼ in. to ½ in. (Average of 3 rates of seeding on Everglades peat soil, 1950, as taken from the original data of Gangstad, Seale, Pate and Joyner, this Volume, page 134.

Figure 2 (right). The vertical distribution of the same kenaf yield values displayed in Figure 1 but shown as total leaf and stalk weights and as green ribbon and dry (retted) fiber yields with the center of gravity indicated for the total crop weight (undefoliated)—a value of considerable importance in the harvesting operation.

The reel of a harvester is intended to give the top of each harvested plant a quick backward movement with such timing of action as to force a "free-fall" condition with the hope that all plants will arrive on the platform conveyor in a like pattern. During the harvesting of a matured grain crop, it is a minor problem to adjust a harvester-binder's parts to give a parallel pattern of moving stems or straws that are assembled into a perfectly tied bundle in which all butts are in line. In the instance of kenaf, however, the heavy leaf growth, as well as the frequent tangling of the stems, prevents the development of independent, "free-fall" relationships. Instead, many stalks will slide down over the cutter bar and, by a series of recuts, be greatly reduced in length and, more often than not, initiate "plugging" at that point. The necessity for exaggerating the

action of the reel in an effort to tear apart the tops of plants, combined with other factors, results in the kenaf canes coming to rest on the platform conveyor in a highly tangled condition.

The total crop, as shown in Figures 1 and 2, under most farm conditions, would represent many difficult problems in handling considering only the factors of weight and length of stalks. This, from the standpoint of transportation, regardless of the harvesting procedure, does not fit existing equipment in questions of loading and unloading in ways that will protect the stalks against added tangling and breakage. Fiber crop producers are particularly concerned, therefore, with the development of ways to reduce the heavy tonnage of waste material removed from fields when the central processing plant is used.

The location of a kenaf crop's waste is indicated in Figure 2. The ideal crop harvester would be one that would continue the machine processing action to at least a ribbon stage, so that the minimum amount of waste material will be removed from the field. A less complex harvester might include a topping and a side disposal attachment. Starting at the extreme top of Figue 2, it is evident that different degrees of topping will have only slow increases in the amounts of fiber losses. Table 2 gives the weight of the topped materials that would be removed at different levels.

TABLE 2.—Fiber Losses in Kenaf as Influenced by Height of Topping, Based on Average Yield Data Reported by Gangstad, Seale, Pate, and Joyner.

Height of Topping from Ground (Inches)	Depth of Topping from Top (Inches)	Green Weight in Pounds per Acre				Dry Fiber Losses per Acre	
		Leaves	Stalks	Sub-Total	Percent of Total	Pounds	Percent of Total
117	12	2,891	00	2,891	5.31	.00	.00
111	18	4,955	24	4,979	9.15	.2	—
105	24	6,985	180	7,165	13.17	4.0	.17
99	30	8,820	466	9,286	19.06	12.5	.53
93	36	10,326	901	11,225	20.63	27.5	1.17
87	42	11,400	1,539	12,939	23.78	52.6	2.24
81	48	12,156	2,391	14,547	26.73	90.4	3.86

The above data shows that a twenty-four inch topping would cause a loss of 4 pounds of dry fibers with a field disposal of 7,165 pounds of green material from the tops alone. This 13 percent saving in transportation is significant. The outstanding advantage from the mechanical standpoint is that the harvested material in reduced length is much more convenient to handle with exisiting equipment. One large decorticator in the Belle Glade area can only process stalks under 84 inches in length. The data also shows topping back 48 inches, or to 81 inches above ground line cutting, gives a field disposal of 12,156 pounds of leaves and 2,391 pounds of green stalks which would represent a loss of 90.4 pounds of fiber per acre. This topping operation as an early part of harvesting operation in the given example would reduce the maximum length of material 37 percent and tonnage of raw material delivered 27 percent.

The crop losses as influenced by the height of stubble after harvesting are shown in Table 3. It is quite evident that the crop should be cut as low as possible.

TABLE 3.—Kenaf Fiber Losses as Influenced by Height of Stubble Based on Average Yield Data Reported by Gangstad, Seale, Pate, and Joyner.

Height of Stubble in Inches	Green Weight Not Harvested		Dry Fiber Losses	
	Total Stalks	Percent Total	Weight	Percent Total
12	10,483	19.18	528.1	22.54
10	8,874	16.31	444.5	18.97
8	7,224	13.27	359.1	15.33
6	5,524	10.15	271.8	11.60
4	3,751	6 89	183.0	7.81
2	1,920	3.53	92.5	3.95

Similar data on the weight distribution relationships in the ramie crop are not available. There is little question that its accessibility would help very materially in analyzing some of the harvesting and processing problems associated with this crop, just as in the case of kenaf, even though they may not be nearly as serious in some respects.

Wind Damage

The two fiber crops under discussion develop a dense canopy of leaves on the tender tip of their stalks. Hard rains and variable degrees of wind will cause a few stalks to break over. These, by cross lodging actions, may entwine and tangle the entire crop in a most discouraging manner. Excessive winds and winds in a close cycle rotation forces even greater disorder in such crops. The degree changes in the disorderly condition of the plants in the field will cause ever-increasing operational troubles with the conventional harvester-binder up to the point that the crop has to be abandoned. In many cases the majority of stalks within the zone of maximum fiber production are not damaged.

Requirements of a Bast Crop Harvester

The service requirements for a bast crop harvester would end with an orderly delivery of clean undamaged canes in such patterns of assembly that they can be transferred with maximum economy and efficiency to subsequent processing operations. The qualification "clean" means the removal in the field of reasonable quantities of waste materials consisting of leaves and such parts of the tops as have been damaged by the wind or are in excess of the capacity, as to length, of a decorticator or other machine operations to follow. The requirement "undamaged" canes is most critical to a processing system that uses an automatic grip-conveyor to pick up and to directly transfer the raw material through a series of machine operations.

It has been made evident that the harvester-binder's first operation, the reel's application of force to the tops of a bast fiber crop, fails to produce an orderly movement and assembly of canes. Attention is also called to the fact that a dividing point and a continuous sliding surface

fails to obtain exact swath division and to aid an orderly delivery o cut canes to the platform conveyor. Snarls of rope-like masses that ca occur in different zones of a growing bast fiber crop really hold the ke to the specifications of the much needed harvester.

The initial harvesting operations must be positive and at a relativel slow speed in the first transitions, which, as further qualifications, mus be in exact agreement with the ground travel of the entire unit. The firs objective is to have each stalk well supported throughout its length befor actual cutting and the starting of the accelerated movements to the poin of discharge from the harvester. In case growth conditions or othe factors cause stalks to interlock over the line of swath division thereb preventing the positively gripped canes from assuming the machin formed pattern of movement, there should be a supplemental mechanism that, at the proper point and time, would sever any plant part that migh tend to prevent the desired action. Subsequently, as the crop is moving through the harvester in a confined pattern, there should be added de vices to remove the tops at any level desired and to throw out other un desirable waste materials.

The ultimate design of a really effective harvester for bast fiber crop cannot now be very fully predicted from known facts. It would appea however, that the corn binder may contain some features of a good basi design for this purpose. Many recent applications of vertical harvesting as used in Louisiana sugar cane harvesters, also might be subject t further modifications for use in handling ramie and kenaf. The logica summary to this discussion is that the creation of a fully satisfactor harvester for bast-fibered crops represents a problem that should wel justify an extensive program of research and development. Certainl it is one that must be solved to at least a reasonable degree before the can be any very considerable expansion of the soft fiber industry in Florida

PRESENT DEVELOPMENTS IN RIBBONING AND DECORTICATION OF BOTH STEMS AND RIBBONS OF SOFT FIBER PLANTS

H. D. Whittemore and Mills H. Byrom *

We have never given up the idea of combining fibers in much the same way we do grain. The field ribboner is a step in that direction. There have been several private concerns and individuals who have tried machines developed to operate in this way. Thus far, none of these have been accepted as satisfactory. However, there is still hope that eventually the fiber may be taken from the field in a finished form and the rest of the plant material left on the ground where it belongs.[1]

It is desired to emphasize the fact that the "Raspador" decorticator, which is universally condemned for its low efficiency and wastefulness, is the only machine that has been able to produce fiber economically in this country. This type machine will handle ribbons of either ramie or kenaf as well as the stalks of either. The ramie ribbons work a little better in the machine because of the stronger fiber in them.

Mention also should be made of the almost unending stream of new inventions and methods that are coming along. There are more than 2,000 patents on file in the United States Patent Office, most of which claim to be the last word in decorticating ramie or any other long vegetable fiber. In spite of this large number of machines, there is still need for more effective methods of decortication.

We at the Everglades Experiment Station have had the opportunity of examining and trying out a great many of these machines, and find that many of them show some promise. It is evident that more improvements will come in all forms of processing machinery as soon as production of the different fibers can be placed on a commercial basis.

If a long vegetable fiber industry is to be established in the United States, we need the type of cooperation from the manufacturer that Mr. Guthrie has shown this morning. Some of the problems that do not seem to have a solution will be simple if the producer and the spinner can get together. Changes that are not too great may be made in the spinning machinery which will enable the grower to produce a fiber that will bring a profit to him as well as to the manufacturer. It is generally conceded that retting of fiber in this country as is done in the Orient can never be accomplished at a profit to the producer. There is the possibility of mechanizing the handling of water retting processes as well as chemical processes which may produce a fiber of equal quality to water retted material. Either of these processes may be developed to the extent that they will be feasible.

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[1] Most of the conditions and equipment referred to in this discussion will be found quite well illustrated in the photo series covering the field trip beginning on page 175.—Ed.

In 1944, we decoriticated kenaf on the raspador decorticator and sent samples to a number of spinners. The fiber was well cleaned and looked very good for mechanically decorticated material. The response from the American Manufacturing Company in Brooklyn was typical of the others. Their comment was: "we have always spun retted fiber, and while there is a shortage at present, we can still get enough to meet our needs. As long as we can, we will continue to use that type of fiber. As to mechanically decorticated fiber, we can make an excellent product from it, but due to the tooling of our mill and the experience of our operators, we prefer the retted material. The mechanically decorticated fiber contains a certain amount of gums and adhering bark and shives which make it harsh and difficult to work. It is also hard on machinery designed for the softer, retted fiber. For these reasons we will continue to use the retted fiber exclusively as long as it can be obtained."

Most of the spinners seem to object to mechanically decorticated material because of the harsh fibers which are stuck together by gums and strips of bark which are apt to bend or rip the pins out of the carding roll, necessitating a repair job that is expensive and complicated and could possibly stop production of an entire line for several days.

We hope that on the trip tomorrow you will be able to see the ribboning machine at work which was shown in the film. The original model is in the Fiber Laboratory at the Experiment Station. In the fields of the American Kenaf Corporation, however, you will see one or more of these machines (they have built three of them) that have been mounted on airplane type wheels, being pulled through the fields following the harvesting and binding of the crop and operating in that manner.

This machine is designed to produce what we call a ribbon. A ribbon in the soft fiber business, is that outer part of a stalk that is retained after the woody interior and the leaves have been removed. It may or may not be whole. Usually it is at least partly broken apart along the line of fiber.

The present machine is a development in the Fiber Laboratory at Belle Glade from what was referred to in the movie as a burnishing machine. This latter machine is a single-drum, hand-fed type. In the original burnishing unit the fiber was fed in thru an opening over the top of the drum, pulled out and then turned around and the other end put through and cleaned in the same way. The ribboning machine has two of these drums and uses a continuous series of cast metal pads mounted on chains with spring pressure on them to carry the stalks along first through one drum which does half of the operation. The grip is then transferred to a second, identical, off-set chain which grips the ribbons produced by the first drum and the partially ribboned stalks are then carried thru a second drum which finishes the job. It may sound a bit complicated when described in this way to people who are not used to some of the machines we work with, but we hope to have you see them tomorrow.

The stationary machine is also useful for other things, primarily for cleaning and straightening dried fiber, the so-called burnishing operation. However, this would be an in-line operation in which you could put the full-length fiber on the feed table perpendicular to it just as in the case of the green stems and take it off in burnished form at the other end. It also could be used in connection with an in-line washing machine for

retted fiber whether the retting was accomplished by natural or chemical means.

As noted before, the machines used by the American Kenaf Corporation are mounted on large-tired wheels and pulled through the field where the bundles are picked up from the ground and spread on a feed table. This operation, of course, follows the binder. It has been pointed out several times that these binders do not make a particularly good bundle. However, the machine that is being developed by Mr. Henriquez has the potentialities of making a nice, clean bundle. If our ribboning machine were to be fed with such bundles, I am sure it would work much more efficiently.

The original intention was to mount the ribboning machine as an attachment on a standard binder of some type which can be drawn through the field. This would cut the crop and feed it directly through the unit. The ribbons would come out the other end and probably thru a double-tie bundling device which should give a bundle that could be carried directly to whatever further processing intended for it. The chief advantage of a field machine of this type would be that it leaves most of the crop waste in the field thus greatly reducing the volume that it would be necessary to transport to and through a processing plant. This, of course, would greatly simplify the waste disposal problem that is ever present where decortication is at a central plant.

After the ribbons are produced there are several methods of processing them. They can be mechanically decorticated as the American Kenaf Corporation is doing at the present time or they can be cleaned either by natural retting or by chemical means. However, we are inclined to agree with the general thinking that natural retting is too slow and expensive.

Chemical treatment for decorticated ribbons has distinct possibilities. Mechanical handling during this process will, of course, be almost essention. As a matter of fact we have gotten quite good results in processing decorticated kenaf fiber by merely boiling in water for a time. The addition of chemicals would naturally cut down on the time but it also would increase the cost somewhat. In the case of processing ribbons it would be necessary for us to make more studies of solutions of several chemicals, detergents or soaps. Under almost any conditions of treatment mechanical action on the fiber seems to be necessary.

THE PROCESSING AND TESTING OF BAST FIBERS FOLLOWING DECORTICATION

T. C. Erwin*

Following the ribboning or decortication of bast-fibered plants such as ramie or kenaf the ribbons must be degummed and cleaned either by chemical means or by natural retting by way of releasing and preparing the contained fiber for spinning. Most of the earlier work that has been done in this field has been discussed in quite a detailed way in a report to the Department of Commerce (1948)[1] from which the covering summary is quoted as follows:

RESEARCH ON DEGUMMING METHODS

A. *General Principles Involved.* The most significant factors involved in degumming ramie fibers apparently are concentration of caustic, temperature, time and degree of agitation. Possibly the most significant single observation made in all the degumming research is the fact that the degumming solution must be effectively changed in the center of a mass of ramie fiber in order to insure that the gums are rendered uniformly soluble.

The gum content of commercial undegummed fiber (decorticated) has been found to vary from 15 to 35 percent, averaging about 25 percent, and consumes (based on average gum content of 25 percent) from 5 percent to 6 percent of its weight of commercial sodium hydroxide in the degumming procedure.

B. *Pressure Degumming.* Pressure degumming, consuming chemicals at the usual rate, has been found to give a very good product if care is taken during washing and rinsing, following the degumming cook, to prevent excessive tangling.

C. *Open Vat Degumming.* This method of degumming has several advantages over pressure degumming, including lighter and less expensive equipment.

D. *Counter-Flow and In-Line Degumming.* A counter-flow technique is in process of development using large tanks and a centrifuge and has been tested extensively with equipment available in the laboratory. It is believed that eventually the commercially acceptable method of degumming will be based on a system of this type, a continuous operating, counter-flow method. A pilot plant model of this system has been constructed in cooperation with workers in the engineering phase of the report and is undergoing preliminary trials as this report is being written at the close of the project.

E. *Souring and Rinsing.* Experiments have shown that an alkali neutralizing (acidulating) technique can reduce the rinsing time by more than half. Acetic acid has been used extensively for this purpose as no deterioration has been noted in the fiber as a result of contact with even quite highly concentrated solutions or of drying in the fiber, should this occur.

F. *Bleaching.* Ordinarily, this operation probably would be completed after spinning and weaving into fabric, but a number of experiments were conducted to determine the effects of bleaching on degummed fiber. It has been found that degummed fiber can be bleached in a chlorine solution to an acceptable degree of whiteness in less than 15 minutes without any apparent damage to the fiber.

G. *Softening.* Experiments have been conducted with a large number of textile softeners from which a variety of finishes have been obtained. These softeners

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[1] *Ramie Production in Florida*, A Progress Report prepared for the United States Department of Commerce by the United States Department of Agriculture and the Florida Experiment Station at the close of Contract No. Cac-47-6 between the Department of Commerce and The Board of Control of State Institutions (1948).

included soluble oils, cationics and sulfonated tallow. Chemical softening is essential before the fiber can be combed or carded.

H. *Reducing Agents.* It has been found necessary, especially in open vat degumming, to use a reducing agent to prevent damage by sodium hydroxide used in degumming. At this time, sodium sulfite and sodium sulfide are considered satisfactory chemicals for this purpose.

I. *Other Degumming Chemicals and Methods.* Patent literature and other literature on degumming were explored extensively and most of the more promising methods were duplicated as closely as laboratory methods would permit. Numerous chemicals were tested and attempts were made to degum ramie fiber by bacteriological action. A number of the chemicals gave quite satisfactory results if the process is carefully controlled. Some of them would be too expensive under practical conditions of operation. Degumming of ramie by retting has given uniformly poor results.

J. *Detergents.* Various commercial wetting agents and detergents were tested in the degumming baths and in the washing and rinsing steps. Sodium tripolyphosphate has proven quite a satisfactory chemical in both the degumming cooks and in the washing and rinsing baths.

K. *Chemical Degumming of Whole, Pre-Stapled Stalks.* Degumming whole, pre-stapled stalks would give the advantage of an accurate staple length, an important consideration in spinning on the cotton system. One of the unsolved problems connected with this type of degumming is the separation of the wood and the fiber after degumming. Separation was attempted by a number of concerns who manufacture fiber cleaning machinery, but without satisfactory results in any instance.

L. *Degumming Fresh, Undried Ribbon.* Tensile strength has been noted to be somewhat less for fiber degummed in a fresh, wet condition without prior drying. Souring before degumming has been observed to assist in the matter of strength values of the final product when degummed in this way. If this procedure can be considered practical, one drying would be eliminated and it would make possible a complete in-line operation for a centrally located ramie decorticating plant.

In a similar manner the methods used in testing and in studying factors affecting the quality of fiber from several standpoints were discussed in the above referred to report from which the summary also is quoted for the quick picture it gives of this phase of the work as a whole:

FIBER TECHNOLOGICAL STUDIES (TESTING)

A. *Facilities.* A fiber testing laboratory, equipped with an air conditioning unit to maintain a temperature of 70° F. and a relative humidity of 65 percent, has been established and equipped with a Scott Tester Model, DH, a Scott Tester IP-4, a flex testing machine and a wear testing machine, with which it is possible to make the following standard tests: tensile strength, sheer strength, elongation or stretch, flex and wear. Other equipment is available for preparing test samples and studying their weight and density.

B. *Summary of Tests Made.* To date, approximately 550 samples[2] have been tested in this laboratory, including many from private industry and several large series from various phases of the research programs in this project. Normal ramie fiber will test, on the average, about 60,000 pounds per square inch on a half inch break made according to the standard procedure for cordage fibers.

C. *Quality of the Fiber as Affected by:* (a) *Maturity of the Stalk.* Samples of fiber from the age studies have been tested to determine the fiber quality as affected by the days of growth of the ramie stalks. It has been found that the tensile strength increases rapidly during what is considered the normal maturity period (60 to 70 days) and continues to increase up to about 100 days; also, that flex life decreases rapidly to the maturity point and then levels off. It would appear that most of the variation noted in tensile strength may be due to the state of maturity of the fiber. Microscopic studies of fiber from immature and mature stalks show the young fibers as thin, flat ribbons with large, collapsed lumens while the more mature fibers show a thickening of the fiber wall and a more cylindrical shape.

[2] To date of this meeting the number of samples tested had mounted to nearly 3,000.

(b) *Variety.* Fiber samples from the variety studies have been tested for physical properties and examined microscopically. Certain variations in tensile strength have not been considered significant but more probably an indication of the degree of maturity of the variety at the time of harvest. Microscopic variations also are believed to express differences in maturity, inasmuch as similar differences were noted in the age studies.

(c) *Fertility of the Soil.* Fiber studies also were made to determine physical properties and microscopic characteristics of samples of fiber taken from different treatments of the fertilizer trials. The differences noted in the laboratory were not considered significant. For this reason, it is believed that growth differences noted in the field will give a more definite indication of fertilizer requirements.

(d) *Manner of Decortication.* Comparative tests have been made using fiber from various methods of mechanical decortication to determine to what extent the fiber strength has been affected. It appears that, within reason, the harsher the mechanical treatment, the less fiber is recovered, but that this fiber is of the greater tensile strength due to the loss of weak fibers in decortication.

(e) *Storage and Age of the Fiber.* It has been demonstrated that there is a rather definite increase in the tensile strength of ramie fiber due to drying and aging before degumming when this operation is accomplished by one of the methods now in use at this laboratory. However, there are hazards in drying and storing, such as mildew, which must be considered.

(f) *Method of Degumming.* Good degumming results have been obtained with ramie fiber using both pressure and open vat methods. The results from a large number of tests made in this laboratory indicate that there is no apparent damage to ramie fiber from steam pressures up to 80 pounds per square inch and no obvious damage from sodium hydroxide solutions in concentrations up to 5 percent when used in conjunction with a reducing agent.

D. *Properties of Ramie Fiber:* (a) *Differential Dye Tests and Uniformity of Samples.* A differential dye test, developed by the Southern Regional Research Laboratory of the U. S. Department of Agriculture to determine the maturity of cotton, has been applied to several samples of ramie fiber with excellent results. Microscopic examination also showed a good degree of correlation when made of samples taken from the age test studies, between cell form and uptake of dye in relation to maturity.

(b) *Microscopic Studies.* Microscopic studies indicate that standard commercial ramie will have a cross section somewhat similar to cotton in shape, but it will be more regular and larger, averaging approximately 8 denier or 50 microns in diameter. The length of the individual cells varies from 1 to 20 inches, averaging between 5 and 8 inches.

E. *Test Methods:* (a) *Standard Degumming Method for Test Samples.* A standard procedure for degumming samples of ramie fiber to test comparatively in the fiber test laboratory and for the age test series has been outlined. This method uses a pressure cook at 40 pounds per square inch in 5 percent sodium hydroxide solution (based on dry fiber weight) 1 to 4 fiber-water ratio, followed by soap cook and acid sour.

(b) *Fiber Test Methods.* For testing ramie on the long fiber testing equipment it was necessary to make a crude yarn. This yarn, or bundle, was cut to a standard length and weight, attached to cardboard tabs, and allowed to condition at least 24 hours in the test laboratory under standard conditions of temperature and humidity. Complete tests include the following: twenty half inch breaks, twenty three inch breaks, six flex and twenty-four wear samples. It is impractical to test stapled material shorter than two inches, and only tensile strength determinations for ½ inch and 0 inch can be made. Manufactured yarns were tested on the IP-4 machine, which determined three-inch tensile strength.

It is readily understood that the work in the degumming and testing fields must be developed in very close cooperation with that in agronomy and engineering because of the many determining factors and influences that are to be found in both of them.

For the purposes of the present review it might be well to discuss a little further three points in particular concerning this phase of the work, namely:

1. Some of the things we have learned from the testing program.
2. Some of the principles involved in degumming, and
3. Some of the problems it is necessary to overcome in making the fiber ready for the spinner.

Naturally, most attention will be given to ramie as that is the fiber with which most work has been done up to the present time and about which we have learned most as a result of the processing and testing program to date. Such a program is not only one of finding facts for their own sake but also for use in establishing a sound basis for the consideration of this fiber as a commodity of commerce relieved as completely as possible from the imaginative qualities that have been conferred upon it by promoters of various qualifications and intent through the years.

In setting up the testing work we started out with a system which is more or less standard for "hard" fibers. Therefore, since ramie is a "soft" or bast fiber rather than a hard, or leaf fiber, the testing procedures are not too well adapted. We have made some modifications and are coming to feel that we are learning from these methods what steps should be taken to set up a better system for ramie. In this way it is hoped that when the time comes and the culture of ramie has become sufficiently extensive there will have been developed a standard system of testing that is much more applicable than at the present, and one that may be adopted the world over.

One of the first adverse criticisms we have heard about ramie is that it has no flex. On this account it has been reported to be no good in certain uses and just doesn't hold up. In other words, if a fabric is creased repeatedly at the same point, as in pressing clothing, it will break at the crease, and all that sort of thing. In consequence of such rumors we decided to investigate this characteristic of the fiber. The first thing we found out was if you take a section of undegummed ramie fiber, it has practically no flex at all -that it is actually quite brittle. As a matter of fact, you can't even get a good tensile strength test on fibers in such condition unless you go to the individual fiber because you can't load a bunch of such fibers evenly enough when the gums are still set in and around them to give a uniform tension on all fibers of such a group. Consequently, when you try to break them under such conditions you break them more or less one at a time and your test value shows up accordingly. We soon learned, however, that if the fibers were properly cleaned and degummed the flex increased very greatly, especially after proper softening. Be that as it may, we are still not prepared to say that flex is one of its outstanding properties especially when compared to nylon and some of the other synthetics.

We also learned that ramie has quite a variation in flex as among the different samples that were tested and we decided to try to find out why. This question of variability seemed to be satisfactorily answered when we got into the study of microscopic cross sections of the different samples.

Thus by studying how the ramie fiber develops it was found that the outside diameter is established quite early. According to the manner of growth the young fiber continues to be quite flat for some time and with a central opening that also is flattish in shape in contrast to the more

nearly round opening of the more mature fibers. Briefly stated, the flattish, immature fibers that are so apparent in the photomicrograph of a cross-section of the stem of a ramie plant are high in flex but low in tensile strength. The tensile strength of the fiber is therefore known to increase with the changing form and the maturity of the plant whereas the flex decreases.

Inasmuch as the position of the fiber in the individual stem relates quite closely to its maturity and form it is readily understandable that we never harvest the crop with all the fiber in the plant at full maturity or with even a reasonably high flex. Those fibers at the base of the plant are most mature, those in the mid-section intermediate in this respect and those near the top the most immature. Consequently there is an inverse gradient running up and down the plant from base to tip, and vice versa, as to tensile strength of the fibers on the one hand and their ability to take flex, on the other. In consequence of these conditions and the present manner of harvesting and processing the crop, it is readily seen that the general, commercial type of fiber usually will have more or less average or intermediate values with respect to both of these qualities.

Since the position in the stalk has a great deal to do with whether you have one type of fiber or the other with respect to qualities of strength and flex and even fineness, that is one of the things which we may be able to take into consideration in future harvesting and processing operations in relation to grades. Of course the manner in which we are going to separate it and the details of such an effort will depend largely on what the limitations and requirements of the spinner are going to be. On account of these fiber quality variations within the plant there has been quite a lot of discussion as to whether we should separate it into top, middle and butt fibers. While this has not yet been undertaken in any practical way, it is possible that much greater uniformity could be achieved by such a procedure in the ultimate characteristics of the fibers and consequently a much closer and more satisfactory system of grade set up. As a first consideration, since the tops of the stalks have much less fiber in them and the fiber is of a considerably different quality than that of the rest of the plant, it might be a good idea to top the plant somewhat lower than might otherwise be considered practical.

Another characteristic of ramie fiber that we have been hearing a great deal about is the almost complete absence of stretch. In other words it is not an elastic fiber as it is susceptible neither to stretching or shrinking. On this account it is coming to find quite an important place in blends, specially with such a fiber as wool which is all but famous for both stretch and shrink. It is said that as little as 25 percent of ramie incorporated with wool will go far in stabilizing a fabric made from such a blending of fibers.

One of ramie's most conspicuous shortcomings is the almost complete absence in it, under natural conditions, of spirality or twist that is so important in causing fibers to cling together and give maximum strength in yarns made from fibers of more or less minimum length. It is on this account in particular that added emphasis is being given to using this fiber in as great length as a particular system will permit since strength is thus obtained thru length. The same idea holds in the use of the finer

fibers in the spinning of finer and finer yarns for the weaving of the sheerest possible fabrics.

In the degumming of ramie the basis of practically all the processes used the world over is a caustic cook in some form. Most of the gums and other materials that are in ramie fiber are not water soluble and, on this account, if they are to be removed effectively they must be treated with some chemical in order to get them into suspension or solution and thus mobile. Actually, decorticated or ribboned ramie fiber will contain from 15 to 25 and even 35 percent gums, depending upon the decortication or ribboning process used. The cleanest fiber is usually produced with the use of plenty of water on the wheels (in the instance of the large centrally located unit) during the decorticating operation. A considerable part of the embedded plant material is sufficiently soluble or suspendable to be removed in this way. Once the fiber is dry it is very difficult to re-wet; hence, without doubt, the considerable soaking periods that Miss Montgomery told us about yesterday as currently used in the Orient.

It seems that the primary problem in the caustic cook is to get the active chemical to each fiber and then to remove the dissolved or suspended waste materials. When you are removing say 20 percent of the gross weight of a material that is quite a large amount that must be handled in this way. In other words, there is not much point in softening the gums then letting a substantial part of them dry back on the fibers where they were before. Therefore, any mechanical action that can be maintained during the degumming process is important. The Japanese process which you saw on the film shown yesterday has the essential points necessary. The only thing is, of course, just as Miss Montgomery said, if you have plenty of hand labor there is nothing to it.

Actually we believe the most efficient process for our conditions will be based on two general principles. One of them is the counter flow of fiber and solution. In other words, remove the waste from the end of the system at which the raw fiber is introduced and introduce clean solution into the end of the system from which the clean fibers are removed. The other item of particular importance in the effective degumming of fibers in such a system is to have a mechanical process that will keep the liquid which is in contact with the fiber constantly on the move. Squeeze rolls are, of course, quite good. This mechanical action can be offset by *time*, however, since, if given sufficient time, the chemicals will diffuse thru the medium and reach the fibers. Unfortunately this does not make for uniformity of the action of the chemical on the entire mass of the fiber both as to concentration of the chemical and duration of the action. In other words the fibers at the center of a given mass are exposed to the weakest chemical for the shortest time.

I should like now to pass on from the problems of degumming to some of those concerned with the preparation of the fiber for spinning. It is believed the primary problem that has been encountered in the spinning of ramie has been in establishing staple length and selecting the spinning system which will take the staple lengths that can be produced. This, of course, is in relation to the almost complete absence of spirality in any form in this fiber in its natural condition. There is one thing which I think should be pointed out in connection with the process which Miss Montgomery showed you that is being used in Japan. Reference is to

the fact that in their fiber preparation operation they produce three kinds of stock and I don't believe that there has been a system developed anywhere else by which you can produce a fine long stapled fiber and get a recovery of about 30 percent of your total original degummed fiber in this longer staple.

I believe I quote Miss Montgomery correctly on their recovering 30 percent of the long fiber while about 40 percent goes to the wool or intermediate system and another 30 percent back to the cotton system. That is certainly a pretty efficient utilization of your fiber stock. Still if you are talking about the price of your very sheer materials and fancy goods you must remember that you are talking of the top 30 percent of your production. We suspect that the secret of the success of the system you saw in the movie yesterday is that big scissors operation. That is the "know how", in that instance coupled with very low-priced but efficient labor, that has provided an effective system under those conditions.

Under the system in common use in this country, once the fiber has been decorticated and dried, the next step is to get it into the best possible alignment preparatory to stapling. This is usually done by brushing or burnishing in order to remove as much of the retained bark and shive as possible and get out those insidious angles and kinks which are certain, otherwise, to considerably reduce the efficiency of the stapling procedure.

At this point it might be well to mention an idea that apparently has occurred to several people since "pre-stapling" while the fiber is still in the plant stem seems to have been tried by a number of operators during the past few years. In other words, these fibers while still in the plant structure are in perfect alignment and that should be the ideal time to staple or cut them into pre-determined lengths, all other conditions being equal. It really sounds like quite a good idea if a method can be developed for handling the chopped stems from the point of stapling on through.

Of course, all the spinning systems have a certain amount of tolerance as to length of staple they can take. Still another process has been tried by at least one mill that is very similar to the one we saw operating in the movie yesterday except they don't use quite as much hand labor. In this method there is produced some kind of a sliver out of the full length fiber. This is stapled and the process is repeated until the desired fiber length is attained and ready for spinning.

If we can lick this problem of preparing accurate staple lengths we can certainly obtain higher "yields" of the type of yarn that we are setting out to make. Actually the normal array of ramie fiber is quite variable. Therefore, we are going to have to take some loss some place along the line if we want to spin ten-inch staple. That, of course, would be our top quality but there will probably not be a very large percentage available in this staple length. It seems that the present trend is to staple from three to maybe six inches on the long end and to try to get the top quality in that range and then recover the tow from that process and use it on some of the shorter methods for a cheaper type of yarn. Thank you.

CHAIRMAN:

Are there any questions? . . . If not I should like to ask Mr. Whittemore if he has anything to add to the discussion of this phase of fiber handling at this time.

MR. WHITTEMORE:

About the only comment I would like to add at this time to what has been said is to more or less re-emphasize the importance of age and varietal studies of bast fiber plants in relation to the quality of the fiber that is to be expected at the time of harvest. Reference is, of course, to fineness of the fiber ("denier") as well as strength and other characteristics such as flex.

CHAIRMAN:

I would like to ask Mr. Walter R. Guthrie, Vice President of Lehigh Spinning Company of Allentown, Pennsylvania, if he will now open the discussion on this general phase of the subject by telling us something about the work he is doing on the mechanization of kenaf harvesting and processing in Cuba.

MR. GUTHRIE:

Mr. Chairman, Ladies and Gentlemen: I suspect that most of you probably heard enough from me this morning. Your Chairman says that I am now to tell you about what is going on in Cuba with regard to the field processing of kenaf. I must first of all tell you there is a lot going on in Cuba that I don't know anything about.

However, I do know something about what one particular producer in Cuba is doing with kenaf; and that is just about the extent of my knowledge of what is going on down there in connection with the development of this crop. Briefly, this Cuban Company asked us to act as a consultant for them in their kenaf program and that is what we have been doing for them this past year.

Having had training in mechanical engineering I try to tackle problems of manufacturing by getting things done on the basis of moving materials about with the least amount of effort. This is because I know definitely in manufacturing, where I have had some experience, that your costs are chiefly built about the cost of moving things around. Actually, running materials through a machine can be done very cheaply. It's the cost of moving them from one spot to another in any manufacturing operation that costs you money. So naturally, when I tackle a job, I try to hold to the greatest practical minimum the amount of effort that is to be expended in this sort of activity.

Consequently when my company took on the job of trying to see what could be done about kenaf for this company in Cuba my first thought was to see how little effort it was necessary to expend in moving things around. So we started with the ribboning of the plants in the field, and what we propose to do is this. We are going to ribbon the plants exactly where they are grown, right there in the field. In this way we are going to get rid of as much of that green material, the waste, as soon as possible for two reasons. The chief reason is we don't want to pay the cost of moving it elsewhere. The second reason is that we would like to leave it right there on the land where it will act as a fertilizer.

Following the ribboning operation we then want to move our ribbons just as short a distance as possible. Naturally we have to move them to a decorticating machine which is semi-portable and which would be located at the nearest source of water. In some cases we are planning on drilling some wells because we think it is a lot cheaper to drill wells than it is to move a heavy tonnage of such material a long distance.

When the fiber comes out of the decorticator, we then propose to move it to a central plant where it will be mechanically dried and baled. The fundamental idea behind the whole process is, then, to move as little tonnage as we possibly can to get the maximum amount of clean dry fiber with a minimum expenditure of energy. Now if we carry through on those fundamental ideas I think we will end up with as low a cost as is possible.

However, when we started with the ribboning machines which were being used in Cuba we first thought they were doing quite a good job. Then we decided that we needed a little different type because we had to end up decorticating that material by mechanical means. And so, in addition to breaking the wood out and getting rid of the foliage we also wanted to get rid of as much of that heavy green material as possible, particularly on the butt ends of the ribbons, so as to lighten the load on the decorticating machine just as much as possible.

While we don't want to tell you too much about this machine, prematurely, when we finally get this operation worked out, and we hope that will be before the end

of November, I am quite sure that the information will be made available to everyone. Although we have designed a machine, in fact this is the third machine we have designed and built, to decorticate kenaf, I can't tell you just where it is at this particular moment—probably somewhere between Allentown, Pa., and Cuba. However, it is our hope that in another week or ten days we will have this unit at work down there. We are going to run it 24 hours a day, 7 days a week as long as there is suitable kenaf in Cuba to put through it. We will then be able to study the results and calculate just exactly what our production is going to be, as well as the costs. This machine may be the answer or it may not be the answer. I am not going to be dogmatic about this thing at all, gentlemen. We are only trying to solve the problem. We are trying to solve it in a little different way than you folks in Florida. In time, you may have the right answer; or we may have the right answer, I don't know. However, what I want is fiber. I don't care whether Florida comes up with the right method or Cuba comes up with the right method, what we all want is a good quality of kenaf fiber produced as economically as it can possibly be done. So that, in general, is what one particular outfit in Cuba is doing.

Now this machine that we think, and hope, is going to be successful, should produce about 600 pounds an hour, theoretically at least, and it is going to take three men to operate it. There will be two men feeding it and one man taking care of the delivery end. So we shall be able to figure out quite simply what it is going to cost to decorticate on that machine. I wouldn't be surprised if we will decorticate for about ¼ cent per pound, that is for labor only with no overhead included. But that, gentlemen, is not as yet a fact. We hope that before the end of November we can say to you that it is a fact.

Mr. Chairman, I don't know whether there is anything else that I should add. There are several new faces in the audience this afternoon in comparison to the morning meeting. I wish that we could again, just very hurriedly, show them your rug here.

CHAIRMAN:

Go ahead, but remember, I promised to give this rug to Mrs. Allison, who so assiduously has been relieving our good members, old and new, of their dues all thru the day at the registration desk. Please don't let anybody run away with it.

MR. GUTHRIE:

I prefer to guarantee nothing on that score after what happened to my kenaf sand bag this morning. However, we have here a finished product, an Axminster rug that is made out of kenaf yarn. About 50 percent of the weight of this rug is kenaf and I think you will agree if you examine it carefully that this fiber does make a very beautiful yarn. And it so happens that about 130-140 million pounds of such yarn is used in fabrics of this kind in this country every year. So you see there is a very good potential market for kenaf yarn right there.

I should like also to again show you this kenaf rope and a few other items made from this very acceptable substitute for jute. Now I am not saying that this is as good a rope as if made from sansevieria. Please don't get me wrong, but for a cheaper farm rope that is very strong and very useful it could be developed into a product of considerable fiber requirement. I would never suggest, of course, that this be used in place of marine rope. As already mentioned, this morning, I had a sample sand bag made for the Corps of Engineers, but somebody seems to have become very much attached to it. However, here are some yarns made from decorticated kenaf that we spun last week. We are now making some samples for the Quartermaster Corps and the Corps of Engineers. This is the finest yarn that we have been able to spin out of kenaf, mechanically decorticated kenaf, that is. This is about an 8½ pound yarn. At first we did not think it was possible to spin the fiber into as fine a yarn as this; but here it is, a fact and no longer just a hope.

I want to emphasize again that what we want above everything else is some fiber production out of Florida. We would like to get a substantial amount of fiber from you people down here. I am quite sure that the soft fiber manufacturers in this country will support your program if you get your costs down to where we can afford to buy it. We are exceedingly anxious to see you people make a success of it; to see a real volume of business built up in this particular field. I guess that is about all I have to say. I will be around for a time if any of you wish to ask any questions.

CHAIRMAN:

Are there any questions anyone would like to ask? . . . It looks as if you have already answered them, Mr. Guthrie. We certainly do appreciate the enthusiastic and helpful part you have taken in both sessions of our program on fiber crops today. It is our hope that ultimately we may be able to give you all the kenaf of the very highest quality that you can possibly use in that wonderful plant you have up there in Allentown of which I have heard so much.

I would now like to call on Mr. Edward G. Henriquez, President, Tropical Fiber, Inc., Vero Beach, for any comments he may care to make on the discussions that have gone before or regarding his extensive experience with kenaf both in Cuba and in Florida.

MR. HENRIQUEZ:

Members of the Soil Science Society and Friends: As one of the first planters of kenaf for commercial purposes, both in Cuba and in the United States, I have been at it for a number of years and, in more or less the hard way, have found out about many of the still unsolved difficulties in the harvesting and processing of this crop.

The agricultural phase of the project has been fairly well attended to. The work under way in Cuba has been quite inclusive and has continued to lead the way insofar as improvement of the plant by breeding and selection is concerned. They are doing more on that phase over there than we are over here because they have had a longer start. They also have had some very good men working on it. On the other hand we are just starting work on this crop over here. I am sure that we will be doing as well, given the same amount of time.

It has been pointed out by several speakers that once you get the crop grown you have to harvest it. We tried to harvest our first commercial crop in Florida in 1949 with the old war-time hemp harvester. This does a fairly satisfactory job insofar as ramie and the shorter kenaf growths are concerned, that is, if you take your time and have plenty of help. The machine is quite complicated, however, and requires an experienced operator as well as quite a bit of mechanical help on the side to keep it going. It does the job, however, and, as the only thing available, it has filled the bill up to now, though it has done especially poorly on the taller kenaf.

However, we are going into commercial production on a very large scale and that has called for a new approach which we and other companies have tried to find. As you have seen from the graphs that have been discussed by Mr. Randolph you have almost as many small, no-account stalks that have very little fiber in them as you do good stalks. This fact impressed us at the very beginning, together with the thought that with the natural orientation of the stems in the field, the method of approach in harvesting should be to try to keep them standing upright in a fully parallel position just as long as possible. This would also include the avoidance of rapid changes in movement, which, when actuated at one point, often cause broken stems.

We have attempted certain basic improvements in our harvester which in brief consists, in part, of a vertical gathering attachment mounted on top of a tractor-trailer mowing machine. The gathering chain is operated near to the horizontal and it is so placed as to grasp and collect only the tall, more mature, fiber-bearing stalks, which are deposited in a windrow at the present time. However, we plan to add a bundling attachment to our harvester in the near future. The gathering chains operating above the tops of the short, immature plants means that they and anything under that height are thereby discarded in the harvesting operation.

We also have attached to the front end of this tractor an elevated cutter bar which can be managed by the operator of the tractor in a way to eliminate the leafy top of the plant. This is done by catching the tops, as they are cut, in a narrow, trough-like conveyor located at the rear of this high cutter-bar which moves them to the side of the swath and drops them on the ground. Thus we have made a composite machine which tops the plants so that the stalks are all of an even height (which is the beginning of your grading system) and then gathers those stalks and cuts them off as near to the ground as the adjustment of the cutter-bar will allow. Thus we avoid the usual high stubbles left by the old binder. In other words we recover more of the lower part of the stalk in which the greatest concentration of fiber is found. By eliminating the shorter plants (about 3 feet and under) in a manner already indicated we are also eliminating the weeds, grass, etc., that otherwise would be included for processing at the next succeeding operation.

Although this fiber question has been covered very thoroughly in this meeting, I am going to digress a bit from the problems of actual harvesting to discuss a little further the importance of high quality, straight fiber which the mills have a right to expect and require. Not only that, they require clean fiber. The cleaner it is the better the price. As was pointed out just a little while ago, ramie grown in China (China grass of commerce) in the past has always been very heterogeneous or ununiform in contrast to the comparative uniformity of the Florida product.[3] The same thing might be said of kenaf grown in India where the harvesting and handling is by hand and the retting and cleaning is usually in foul, silt-laden water by the same primitive means; likewise in the instance of abaca grown in the Philippines in which I know that sometimes the losses run as high as 50 percent on a weight basis because of dirt and trash of many kinds that have been found in the bales that come from off-shore. Fiber conditions can explain why Florida ramie at 28-30 cents per pound might be preferred to the China Grass of Commerce even though the latter has sold as low as 3 to 8 cents per pound! All of this I mention largely to bring us back to the point Mr. Guthrie brought up a while ago, that we have got to prepare for 12 cent fiber in the instance of kenaf if the industry is to survive though quality production on our part may quite appreciably broaden this price base since, after all, it is clean, straight quality fiber that the manufacturer wants and its losses in the manufacturing process are comparatively small.

In the harvesting procedure[4] we are developing, as has already been explained, we are eliminating and leaving trash in the field which at the present time is only adding weight to our handling and hauling costs and cluttering up the machines which do the harvesting and ribboning or decorticating. That is to say, all that trash that the old harvester-binders pick up and put into the bundles along with the good plants creates volume and weight which has to be handled and re-handled and this costs money. In the end it also reduces the quality and value of the fiber produced because the small, short fibers that do get through tend to degrade the fiber that you are selling. Therefore, in my opinion, we have to start right at the very beginning in harvesting and eliminate as much of the undesirable material as possible.

I sincerely hope that tomorrow, in the course of the field trip that has been planned to the Glades, we will be able to show you this first attempt at approaching the harvesting operation from a new point of view for these tall, fiber plants. The appearance of the field behind this machine is not as neat and tidy as it is following the passage of the old type of machine because it doesn't pick up all the trash. It leaves it on the ground where it belongs. Many small stalks lying there make you think that it is inefficient and doing a poor job. Perhaps it is actually being a little bit too efficient. However, it is greatly reducing the mass of plant material that must be handled and from which you are really going to get the better quality of commercial fiber. Thank you.

CHAIRMAN:

Thank you, Mr. Henriquez. We are happy to have Mr. Joe Walker with us this afternoon. Mr. Walker is presently Director of the U.S.D.A.'s cooperative fiber production study in Cuba. He will now tell us something of the work with kenaf that is under way down there in cooperation with the Cuban Government.

MR. WALKER:

Mr. Chairman, Members of the Soil Science Society, Ladies and Gentlemen: In my opinion one of the most interesting things about this kenaf program hasn't been mentioned today. I refer to the history behind it. While such a discussion may not have any particular economic value perhaps you might be interested in hearing something of it.

Kenaf was first introduced into Cuba in 1918 and the seeds were lost in a year or so. It was reintroduced in 1933 and the project went so far at that time as to

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[3] This was very strongly emphasized by Mr. Harry Neiman, Sea Island Mills, Inc., in his talk on the subject of degumming before the Society at the time of its meeting in Belle Glade in April 1947 as reported in Proceedings Volume VIII, pp. 141-143, 1946-7.

[4] Note: A couple of views of the new type of harvester which Mr. Henriquez has discussed and a view of the ribboner he is developing are to be found as Figs. 2 and 3, page 243 of the Appendix.—Ed.

develop plans for the construction of a sack mill when the seed sources were lost again. However, in 1942, Mr. Acuna and an associate of his in the Cuban Government brought in fresh supplies from San Salvador and from that time on we haven't lost the kenaf seed supply. At that time Mr. Acuna brought back three pounds and on account of this introduction and the care given the seed he might be regarded as the father of the modern kenaf program down there.

A few months after that, in 1943, an army bomber flew over from San Salvador and left seeds in most of the West Indian Islands. Some four or five hundred acres were grown in Cuba that year. Enough seeds were produced the following year, Mr. Guthrie, to decorticate over 20,000 pounds of fiber. And it was fiber from that crop that was used to make the first sugar sacks that we made from Cuban kenaf. However, when the time came to make those sacks we couldn't find a mill in the United States that could weave them until we happened to learn that there was a small pilot-sized jute mill in San Quentin Prison. A fair sized sample of the fiber was first sent to Pennsylvania for spinning and thence to the San Quentin Prison for weaving. About five sacks were woven from it.

Since that time most of you are familiar with the modern kenaf program. When that plane landed those seeds in Cuba none of us had heard anything about kenaf and Mr. Horne, who was then working in the Experiment Station in Puerto Rico, received orders to go receive a load of kenaf seeds which the Board of Economic Warfare was sending. He and Mr. Acuna, working with officials in the American Embassy in Havana, then developed a cooperative program to answer the current need. It was from this that the present program grew.

I first went to Cuba in 1945. My predecessor there, Dr. Julian Crane, did the preliminary agronomic experiments and my work more or less expanded and substantiated what he had already found. I think one of the most important contributions we have made down there that has not been given much attention, as yet, because of the overshadowing problems in the mechanical extraction of the fiber, is the breeding work that has been done.

Those seeds that were introduced from Salvador were a mixture of four varieties. They came in a very round-about way to Salvador, we think from Java. They reached Java in the hands of a Dutch diplomat who gave them to one of the representatives in the diplomatic service of San Salvador who took them back to the President. A small supply of these seeds was given to an American who thought that they might have a future down there and so he multiplied them to the more than 2,000 pound supply that was sent to the West Indies by 1942. Previous to that time some kenaf seed had been sent to Peru and the best information we can get is that those also came from Java though they do not bear very much resemblance to the ones we got from Salvador. In 1945, however, we also introduced those into Cuba and I made some crosses of the two varieties introduced in 1947. As a result we now think the prodigy of some of those crosses will open up about 20 degrees of the Earth's surface as a belt around the equator for kenaf production where, before, it was thought that this crop could not be grown. These new strains are not so sensitive to day length as the earlier ones we were working with and it appears that they will produce fiber down closer to the equator where there is a heavy rainfall and exceedingly fertile land and the plant makes very rapid growth. We had nine-foot kenaf in sixty days in Salvador this year. I planted kenaf seeds there one Wednesday afternoon and by Sunday morning the young plants were three inches tall.

With reference to the extraction work that all of us are doing, I can't add much to what has already been said. We all seem to be pursuing essentially the same course and using more or less the same methods with some small variations. I believe the best thing we can do, and I think my Cuban associates will endorse this, is to invite you to come down there and study our work just as you have so cordially allowed us to study your work up here. I am sure you will always find our latch string out just as we are finding yours up here.

In certain cultural operations we are doing a little differently down there but I don't think the difference is sufficiently great to try to point them out here, especially since our conditions are so different. Thus we don't exactly agree on the methods of harvesting seeds. We are not going to combine ours directly, certainly not the Kenaf Corporation. However, some of the other growers are going to try it. We fear that there is going to be too much moisture in the seeds if they are threshed directly in this way and we would run into trouble from moulding, and consequent loss of viability. The Kenaf Corporation is going to cut the seed crop with binders, let the bundles dry in shocks and then thresh them. Last year we found that we

could run our yields up quite appreciably by harvesting in this way. We have combined successfully in Cuba but the yield has always been low. I don't recall any yield from combining ever running over 250 pounds per acre. Last year we had yields running over 600 pounds by using binders and then threshing. That was on areas of up to 33 acres. We actually averaged over 400 pounds on more than 200 acres by harvesting in this manner.[5]

Of course you should cut the kenaf when you think you will get the most seed. In Cuba, then, we recommend harvesting for threshing when there are three to five dry capsules. The greener the stems are the smaller the bundles and shocks will have to be so as to get good ventilation. If your kenaf is perfectly dry there is no reason why you should not combine it. Unfortunately, we don't get it dry enough down there until it is so late that most of the seeds are lost.

Thank you for your attention. I'd be glad to try to answer any questions that any of you may have.

QUESTION:

What kind of binders do you use?

ANSWER:

We are using the so-called war-hemp binder which was originally a John Deere harvester-windrower for hemp to which has been attached an International binding head.

QUESTION:

What kind of thresher are you using?

ANSWER:

We are using International threshers and International combines, as well as John Deere and Massey Harris.

QUESTION:

Do you have to change the threshers?

ANSWER:

No. They are all made for rice and we have made no modifications on them except to adjust the screens. They all have adjustable screens.

QUESTION:

Do you have to tie the shocks?

ANSWER:

No. We don't tie them. Many of them fall down but we go back and set them up again. We shock them with open centers, so the air can get through them. Kenaf will carry 85 percent moisture in wet weather when it is green.

CHAIRMAN:

Are there any more questions? . . . If not, we would now like to hear from Mr. DeWitt Knox, Vice President of American Kenaf Corporation, who has been exceedingly busy during the past few months setting up the Corporation's large Mohegan Corona decorticator and getting it into operation on kenaf out in the Glades.

MR. KNOX:

Mr. Chairman, Ladies and Gentlemen: Since the discussion would seem to be about at an end I don't know whether I am to be considered lucky or unlucky. Perhaps I am sort of a fifty-fifty individual because the good services of the Experiment Station and of the Department of Agriculture have given me lots of help as well as lots of headaches. I think if Mr. Whittemore had spoken to me this morning about the disadvantages of the field ribboner I might have helped him out quite a little bit. We have decided to try this field machine by building three of them and I never know when I get up in the morning whether I am going to have a headache or a picnic. Up to now I've had lots of headaches.

Our field program out there is essentially as outlined by Mr. Guthrie in connection with the work he is doing in Cuba. We have taken this U.S.D.A. machine

[5] The binder and combine to which Mr. Walker refers are shown in the photo series covering the Field Trip, beginning on page 175.—Ed.

and, with the help of workers at the Experiment Station, undertaken to adapt it to producing ribbons from kenaf and carrying them to the central decorticator which, in our case, happens to be a Mohegan Corona type as referred to by the Chairman. We run these ribbons through the decorticator and get a limited amount of nice clean fiber which is ready for drying and baling.

There has been a terrific amount of work done by the Agricultural Department of the Corporation in getting about 700 acres of land ready and planted. They have done a marvelous job and have really been pushing me with those plants. As has been said, if you were to go south on Highway 7 you would see some fields of kenaf in blossom that are intended for seed production. However, if you come out to our plantation tomorrow you will find that we are growing our crop for fiber and not for seed. Consequently we are harvesting and producing fiber at this time.

I don't exactly know what the chairman had in mind when he suggested that I take part in this discussion. Unfortunately, I was so busy in the field that I could not attend the meetings yesterday and this morning. However, from what I have heard this afternoon I feel that about all the salient points have been very well covered. However, there is nothing like a physical view of what you have heard discussed so I hope you will be able to come out to see us tomorrow. Do you think of anything else, Mr. Chairman, that I might add to this discussion?

CHAIRMAN:

Not unless you might be willing to idealize a little bit and tell us just what you would like to have in the way of equipment to more efficiently handle the crop you are working with.

MR. KNOX:

Mr. Byrom expressed my thoughts perfectly when he said we need a machine that will handle production with low waste. My principals come out there and look at what I am doing and say the waste is terrible, can't we do something about it! Of course, all that waste means dollars, plenty of them, and the quicker somebody develops a machine that will turn a larger percentum of the fiber contained in those plants into money, why the sooner we will all be a lot happier.[6]

CHAIRMAN:

Are there any questions you want to ask Mr. Knox before he scoots back to the field? . . . If there are none I should like to again remind those of you who plan to go on the field trip tomorrow to let us have your name on the list just as soon as possible. The principal stopping points will be at Newport Industries, Inc., where the ramie harvest is actually under way, then the Everglades Experiment Station, followed by the plantation of the American Kenaf Corporation, where the first harvest of kenaf on a large scale in Florida thru the use of mechanical decortication is under way. The bus will leave the hotel at 9:00 A.M. There is no meeting this evening

Before closing the afternoon meeting, however, I should like to call on Mr. Georges Brouillette of Clermont, Florida, who has been working with Dr. Charles R. Short during the past couple of years at the Florida Industrial Laboratories in that city on certain ribboning and degumming devices for the harvesting and processing of bast fibers. Unfortunately, Dr. Short could not be with us today on account of illness.

MR. BROUILLETTE:

Mr. Chairman, Ladies and Gentlemen: I am indeed glad to say a few words regarding our work up at Clermont for Dr. Charles R. Short, who, being ill at this time, could not attend this meeting, as your Chairman has said. I can assure you that he would have liked very much to be here with you.

As many of you know, Dr. Short became interested in the possibilities of a soft fiber industry in Florida some eight years ago and has made extensive studies since that time of the many problems that are involved. After much thought and consultation with many fiber specialists, it became apparent that the pricinpal "bottleneck" was in the mechanization of the harvesting and the ribboning or decortication of

[6] Some of the operations on Am. Kenaf's Plantation will be found in the photo series covering the Field Trip beginning on page 175.—Ed.

such plants; and that if these types of fibers were to be produced economically in Florida new machines for this purpose would have to be developed.[7]

With this in mind he diligently set himself to the task of designing and building a small type of ribboner that the individual farmer could buy and operate economically. Tremendous strides have been made in these developments. Dr. Short's health permitting we will make field tests of the ribboning machine in the near future.

It has been my pleasure for the past year and a half to work for and with Dr. Short in the building and testing of this machine. As a matter of fact we have been working on two machines, the one referred to above we call a field ribboner or decorticator; the other is a chemical degummer and washer for cleaning up the ribbons of either ramie or kenaf by way of preparing them for further processing and spinning.

All of this work has been helped to a great extent by the ever-cooperative efforts of Dr. Allison and the staff at the Everglades Experiment Station. I thank you for this privilege of speaking to you.

CHAIRMAN:

Thank you, Mr. Brouillette. I am sure we all hope for Dr. Short's complete and speedy recovery. Will you kindly convey our every good wish to him at the first opportunity! If there are no other questions . . . the meeting is adjourned.

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[7] A general view of the field ribboner developed by Dr. Short will be found on page 243 in the Appendix, Figure 1.

EVERGLADES FIELD INSPECTION TRIP FOR RAMIE, KENAF AND SANSEVIERIA

October 31, 1951

A group of more than 50 delegates left the George Washington Hotel by chartered bus, and many others in private cars at 9 o'clock on the morning of the 31st, following the close of the Annual Meetings of the Society on the afternoon of October 30.

The FIRST STOP was at the plantation and mill of Newport Industries, Inc., east of Canal Point. The general operation of this unit in the field and in the mill was fully explained by Mr. J. M. Dempsey and his associates to whom the entire group was deeply indebted for such a complete view of the operation which has become of world-wide interest. The series of photos that follow show some of the operations involved in this project, though all of the pictures were not necessarily taken on the day of the tour.

NEWPORT INDUSTRIES (Ramie)

Figure 1. An early air view of the central plant at Newport Industries, Inc., Canal Point, showing extensive areas of ramie in the background and yard-drying of the fiber, a practice that has been discontinued in favor of oven drying as illustrated in Figure 12 of this series.

Figure 2. Digging ramie roots with a potato digger for planting new areas. While this operation was not observed during the inspection of the plantation operations, this is the way it is being done.

Figure 3. Gathering the roots that have been surfaced by the operation in Figure 2 preparatory to chopping and planting.

Figure 4. Planting ramie roots, 4 rows at a time, from rhizomes and crowns that have been harvested and gathered as shown in Figures 2 and 3. The rows are spaced three feet apart with planting pieces dropped at intervals of about two feet in the row.

Figure 5. Air view of harvest operations on the plantation of Newport Industries, Inc., showing three binders and two loaders in action with numerous field wagons awaiting loading. The seemingly limitless expanse of the Everglades is well shown in the background.

Figure 6. Close up of harvesting operation with war-time hemp harvester. Note self-tripping bundle carrier at right which was designed by and built for Newport Industries, Inc. This will carry a load of 800 - 1000 pounds and saves the hand labor involved in piling bundles manually.

Figure 7. Close up of grapple hook and Speed Loader mounted on D-4 tractor as adapted to loading sugar cane and, in this instance, ramie. Note the piling of bundles in the background preparatory for the use of the loader. This was before the bundle carrier had been installed on the harvester.

Figure 8. A close-up of loading operations using a Speed Loader to rapidly fill the train of Athey wagons.

Figure 9. Arranging ramie bundles on feed table at central plant as the apron approaches modified Corona decorticator at the left.

Figure 10. Ramie mat approaching decorticator at end of feed table on the left and decorticated fiber leaving the machine on the right. Note the two encased raspador units, one in front of and the other at left of man at top of picture and waste leaving upon separate carriers from each thru the back of the building.

Figure 11. Decorticated ramie fiber after passing through the squeeze rolls which remove a considerable amount of the free water it contains as it leaves the Corona where it has been thoroughly washed during the decorticating process.

Figure 12. From the squeeze rolls the wet fiber is taken to the drying ovens via the "dolly", as shown in this photo. Thus only a few minutes after decortication has taken place the fiber is dried and ready to bail.

Figure 13. Bailing dried, undegummed ramie fiber after it comes from the oven in preparation for storage or shipment.

Figure 14. Weighing and warehousing bailed ramie at Newport Industries, Inc., Canal Point. Here the product is at an intermediate point between field production and industrial use.

Figure 15. Manufacturing ramie leaf meal from the tops of the harvested plants. This is a high protein (22-24%) feed for livestock and poultry. Although its manufacture has been temporarily shelved in favor of chemical defoliation in the field, there is always the possibility that it will be resumed in due course.

Figure 16. Undegummed ramie in wrapped bales in process of loading for shipment from Canal Point. The wrapped bales are for export. Mr. J. M. Dempsey, manager of the Fiber Division of Newport Industries, Inc., at Canal Point, is shown holding a small armful of the undegummed fiber.

EVERGLADES EXPERIMENT STATION

The SECOND STOP, following luncheon in Belle Glade and elsewhere along the route, was at the Everglades Experiment Station, about 2½ miles east of Belle Glade on the Palm Beach - Ft. Myers highway. Here a considerable amount of investigational work and research is under way on the agronomic and engineering problems associated with fiber crop production in South Florida — particularly ramie, kenaf and sansevieria — as discussed during the two days of meetings that immediately preceded the field trip. As in the instance of the field inspection of ramie at Newport Industries, Inc., only a few of the high points of this stop will be shown in the figures that follow. These will include reference to various problems observed and discussed along the way though not necessarily seen or discussed at the time of the Experiment Station visit.

Figure 17. Air view of the Everglades Experiment Station from the north (left) and (right) from the south showing more details of plot layout to the right of the roadway running across the lower, left-hand corner of the picture.

RAMIE

Figure 18. Ramie variety plots at the Everglades Experiment Station.

Figure 19. A good stand of mature ramie ready for harvest.

Figure 20. Ramie inflorescence with female type blossom above and the male, pollen bearing type, below.

Figure 21. Partially decorticated stems showing the peripheral location of the bast fibers and their abundance in this type of plant.

Figure 22. Ramie flow-chart showing various steps in processing and use of the fiber from the crude, decorticated ribbons ("China grass" of commerce) to the finished yarns.

KENAF

Figure 23. Kenaf blossom. Note the hibiscus type.

Figure 24. Section of mature kenaf stems, at left, with seed pods, center, and seeds exposed, on right.

Figure 25. Kenaf variety plots at Experiment Station with Mr. Charles C. Seale, fiber crop agronomist, as the "measuring stick".

Figure 26. A mature growth of kenaf at about 110 days of age on a typical mineral soil, Pompano fine sand, in the Indiantown area.

Figure 27. Harvesting mature kenaf for seed with a war-time hemp binder. This is an operation of Tropical Fibre, Inc., Vero Beach, Florida.

Figure 28. Field view of kenaf shocks ready for threshing with the combine shown at the right. This is an operation of Tropical Fibre, Inc., Vero Beach.

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

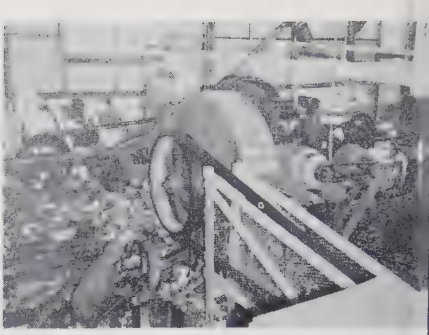


Figure 10

Figure 11

Figure 12

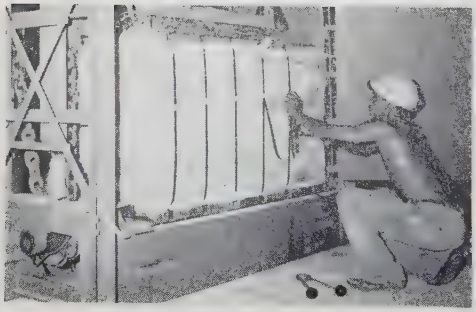


Figure 13

Figure 14

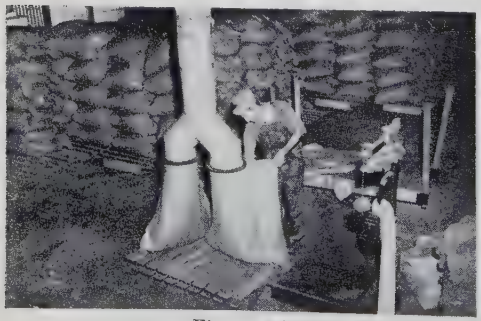
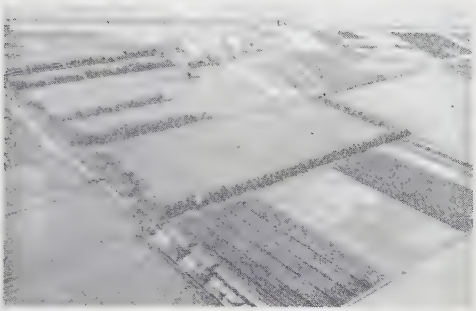


Figure 15

Figure 16

(Left) Figure 17 (Right)



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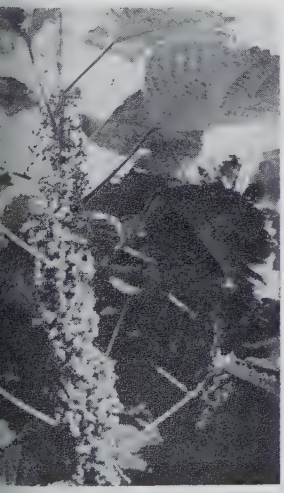

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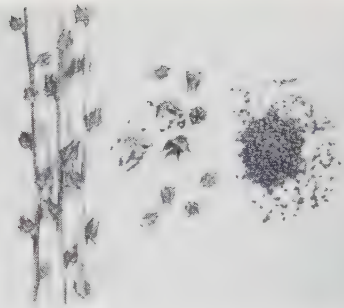

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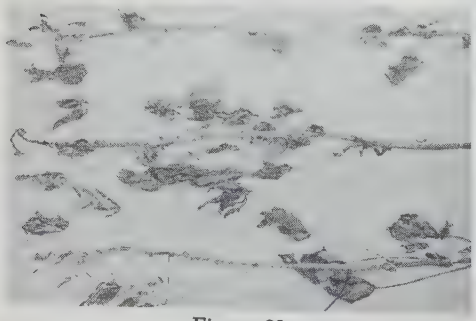

Figure 29

Figure 30

Figure 29. Top blight of kenaf which was thought by some at the time of the meetings to be a form of virus disease but later found to be definitely associated with infection by *Colletotrichum*, sp.

Figure 30. An area of plants in a kenaf field badly affected by the root-knot nematode with the almost complete destruction of the root system as shown by the inset photo of plant roots from another area.

Figure 31. Harvesting problems can be caused by the wind when the kenaf crop is mature and heavy in the top growth. The wind was not blowing at the time the picture was taken as might be judged by photographer Averill's mussed hair and the bowed plants.

Figure 32. Harvesting problems also can be the result of planting kenaf seeds contaminated with morning glory: Above—ground view of the impossible condition that developed in the course of only a few weeks of growth with an air view of the same field (below) showing an exploratory path that had been cut across it with the harvester before the flight photo was made, in an effort to determine the extent of the infestation. Such a condition forced abandonment of this entire 80-acre field as well as several others.

Figure 33. This is a part of the kenaf waste referred to in the discussion of the decortication problem by Mr. DeWitt Knox towards the close of the program in West Palm Beach just prior to the field trip.

Figure 34. A large part of the harvesting difficulties associated with the handling of bast fibered crops, such as ramie and kenaf has been associated with the derelict equipment it has been found necessary to use up to the present time. Thus, the war-time hemp binder, a poor job though it has done, is no longer made and many of the critical parts necessary for replacement no longer can be obtained except by special order. All credit to it, however, for the start it has given the bast fiber industry in Florida.

SANSEVIERIA

Figure 35. A cultivated stand of *Sansevieria thyrsifolia* Thunb. (*S. guineensis* Willd.) growing in mineral soil at Boyton, Florida.

Figure 36. Decorticating demonstration at the time of the field trip with the large, Corona-type machine built to the design and specifications of U.S.D.A. engineers by a Baltimore firm. The first drum is readily visible between the two men at the feed table, Mr. Byrom, right, and Mr. Whittemore, left.

Figure 37. Standard bale of sansevieria fiber weighing about 400 pounds as prepared at the Everglades Station for U. S. Navy tests. This was taken from plants gathered from widely distributed areas over South Florida.

AMERICAN KENAF AND FIBER CORPORATION (Kenaf)

The THIRD AND LAST STOP on the field trip was at the Plantation of the American Kenaf and Fiber Corporation on the lower Hillsboro Canal southeast of the Experiment Station and really out in the heart of the Everglades. In view of the fact that this entire operation was broken out of virgin, sawgrass soil (Everglades peat) beginning only a little more than a year before the time of the visit, August 1950 to October 1951, photos of several of the land-preparation operations will be included in the figures that are to cover this stop. The whole party is indebted to the officials of the above corporation for their hospitality and the completeness of the study which they were permitted to make of the entire operation.

Figure 38. Native sawgrass of the Florida Everglades. It is from the roots of this heavy sedge that Everglades peat largely has been formed.

Figure 39. "Chopping", is one of the first land-preparation operations in the Everglades where there is not too much heavy shrubby growth such as willow. It simply consists of running the heavy vegetation down so the plow can turn it in.

Figure 40. Plowing the brown, fibrous peat with a two-disc unit.

Figure 31

Figure 32

Figure 33

Figure 34

Figure 35

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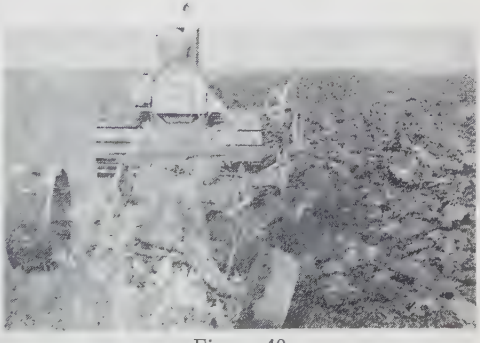
Figure 38

Figure 39



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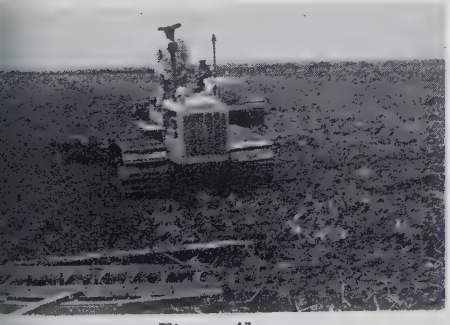

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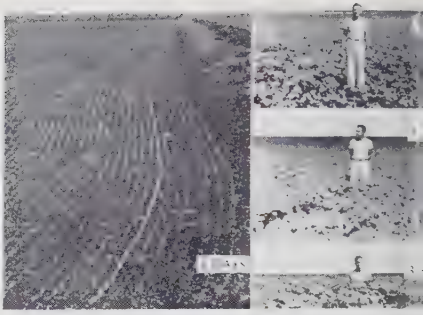

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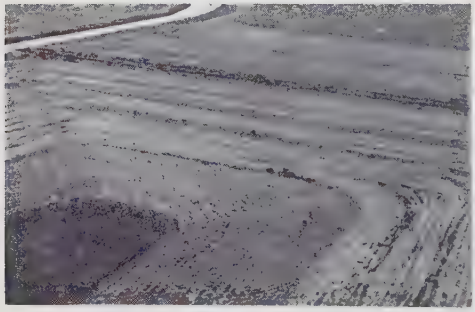

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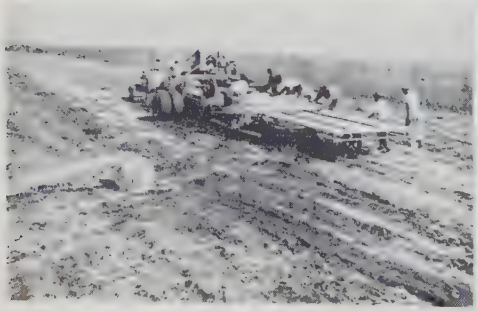

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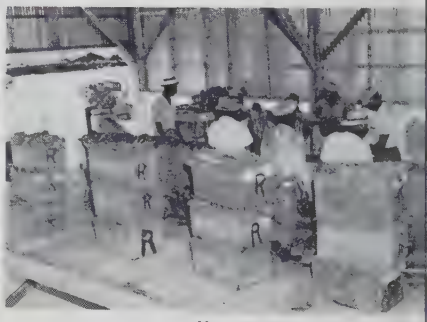

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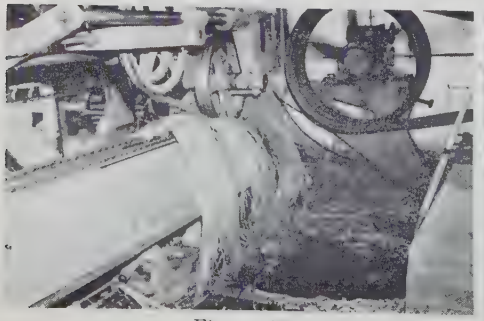


Figure 49

Figure 50

Figure 41. Harrowing and leveling the peat soil after plowing. The fibrous character of this soil is well shown in this operation.

Figure 42. Distributing fertilizer broadcast by drilling just prior to seeding.

Figure 43. Drilling kenaf seed with a standard rice drill. For fiber production the rows are spaced about 7 inches and rate of seeding about 20 pounds per acre, depending somewhat on viability of seed.

Figure 44. The growth rate of kenaf in the moist, warm Everglades peat is well shown by the photos taken at 2, 7, 15 and 35 days following seeding.

Figure 45. The kenaf harvest as viewed from the air. Center, uncut, showing binder in operation with a twin-drum ribboner working at the outer edge of the bundle-strewn area. Note difference in appearance of bundle covered area and the trash left after the passing of the ribboner.

Figure 46. Ground view of one of the modified hemp binders at work harvesting kenaf. Note loose, poorly tied bundles.

Figure 47. Ground view of twin-drum ribboner at work. This ribboner was developed by U.S.D.A. workers at the Everglades Station. Note scattered boxes of ribbons awaiting transport to the central plant for decortication.

Figure 48. Ribbons from field boxes being placed on the decorticating line at the central plant.

Figure 49. Field ribbons entering the first wheel of the decorticator. This procedure was never developed to a point where the losses of fiber were not excessive.

Figure 50. Kenaf fiber leaving the squeeze rolls and ready for the drying oven.

Figure 51. Kenaf entering (above) and leaving (below) the experimental drying oven at the Everglades Station where most of the 1951 crop was dried.

Figure 52. Kenaf fiber in the bale, warehoused and ready for grading.

Figure 53. Yarns and burlap bagging in various forms manufactured from mechanically decorticated kenaf.

Figure 51

Figure 52

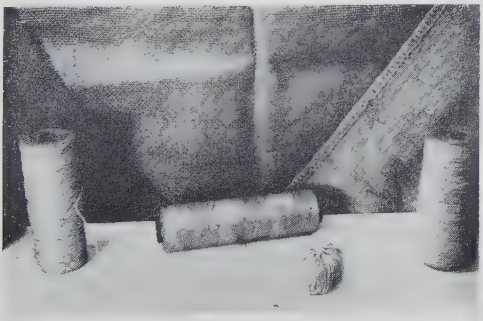


Figure 53

BUSINESS MEETING

A brief business meeting was called by Vice President Wander immediately following the close of the Panel Discussion on Soil and Water Conservation on the evening of October 29. Dr. Wander presided in the absence of President Carrigan.

A telegram was read from Dr. Carrigan expressing his deep personal regret over his inability to be present at the meetings due to the heavy responsibilities of his new position at the Armour Research Foundation in Chicago.

Chairman Wander announced that essentially the only business to be taken care of during the meeting was the election of a Vice-President, the present Vice-President, according to the dictates of the constitution of the Society, automatically becoming President by that action.

The Nominating Committee that had been appointed during the morning meeting, which was made up of Dr. W. T. Forsee, Jr., Mr. E. B. O'Kelly and Mr. V. E. Woods, with the last named acting as Chairman was asked to report.

In presenting the report Mr. Woods advised that the committee had met during the late afternoon. It seems that after having heard a certain paper during the morning meeting on "Sodium and Potassium Interrelationships in Pangola Grass" they came rather quickly to the unanimous decision that Dr. Nathan Gammon, Jr., should be nominated to this important responsibility. After formally nominating Dr. Gammon to the elective office of Vice-President of the Soil Science Society of Florida as the choice of his committee, Mr. Woods then took the opportunity in behalf of the committee, to move that the nominations be closed and that the Chair instruct the Secretary to cast a unanimous ballot to certify his election. Following the usual call of the Chairman for nominations from the floor, and receiving none, a second to Mr. Wood's motion was requested and received simultaneously from a half dozen or more members. No negative vote being received, following the question, the Chairman followed the usual convention and instructed the Secretary to cast a unanimous vote by which Dr. Gammon became the new Vice President for 1952.

The Secretary was then asked to read the Resolution of Sympathy that had been prepared for members who had departed this life during the year and requested a short pause after the reading. The resolution will be found on page 187 of this Proceedings.

There being no other business to come before the meeting the President asked for a very brief meeting of the Executive Committee immediately following adjournment. The meeting was declared adjourned at 10:45 P.M.

MEETING OF EXECUTIVE COMMITTEE

At a short session of the Executive Committee President Wander, as Chairman of that Committee, extended a cordial invitation for the Society to hold its 1952 meetings at the Citrus Experiment Station, Lake Alfred. This was tentatively accepted and program plans discussed in a preliminary way. In filling the position of Secretary-Treasurer, R. V. Allison of Belle Glade was again appointed to that post. There being no other business to come before the committee the meeting was adjourned at 11:15 P.M.

RESOLUTION OF SYMPATHY

Soil Science Society of Florida

WHEREAS, death has taken from our rolls during the year 1951 the following esteemed members of the Society whose sincere and constructive interest in all aspects of the work will make their absence keenly felt for a long time to come,

NOW THEREFORE, BE IT RESOLVED, that this expression of sorrow over this great loss and of sympathy to the immediate families of the deceased be spread upon the records of this Society and a copy of same be sent to the closest member of the family of each.

MR. EDWIN L. ANDERSON
Lima, Peru

DR. B. R. FUDGE
Jacksonville, Florida

MR. E. T. HALTER
Palm Beach, Florida

MR. B. G. KLUGH
Birmingham, Alabama

MR. R. K. LEWIS
West Palm Beach, Florida

MR. G. A. NICOL, JR.
Palm Beach, Florida

MR. HARRISON RAOUL
Belle Glade, Florida

MR. J. GLENN RAWLS
Plymouth, Florida

MR. J. D. WARNER
Quincy, Florida

MR. J. S. WILLSON
Palm Beach, Florida

By the Resolutions Committee,

LUTHER JONES, *Chairman*

A Resolution Addressed Particularly to the Various Boards of County Commissioners of the Central and Southern Florida Flood Control District, Pertaining to the Urgent Need for Their Fullest Possible Cooperation in the Planning and Construction of Roads and Highways as an Operation of the Very First Importance in the Organization of Any System of Water Conservation and Control for a Given Area That Is Economical in Its Construction and Maintenance and Efficient in Its Operation.

WHEREAS, the adequate conservation and handling of Florida's water resources has rapidly mounted to a place of very first importance during the past few years because of rapid increase in population and extension of agricultural development; and

WHEREAS, the development of a system of roads is as necessary in promoting the use of the lands as the construction of the system of water control; and

WHEREAS, the construction of ditches and grades and other physical installations and adjustments normally associated with proper road and highway planning and development can become an item of first importance, either for better or for worse, in the planning of a proper water control installation for a given area and its subsequent maintenance; and

WHEREAS, The Board of County Commissioners, as duly elected public servants, exercise a very great amount of authority in determining the location, design, construction and maintenance of highway and road systems in their individual counties and consequently in the State as a whole both on their own responsibility and in cooperation with the State Road Board.

NOW, THEREFORE, BE IT RESOLVED, that this meeting go on record as importuning, through this resolution, all Boards of County Commissioners in such counties or parts thereof as fall within such water control units as Central and Southern Florida Flood Control District to take the fullest possible cognizance of these needs for coordinated effort in all matters pertaining to Water Control and Conservation and to give the fullest possible cooperation in the physical development of same insofar as co-operation in the location and design of roads and highways and physical installations pertaining thereto are found, or could be found, to play an important and helpful role in this vital phase of our conservation planning for the future that is so vitally needed.

BE IT FURTHER RESOLVED that a copy of this resolution be sent, at the time of publication, to the Office of the Governor; to the Commissioner of Agriculture, Tallahassee; to the District Office of the Corps of Engineers, U. S. Army, Jacksonville; to the Chairman of the State Road Department; to each Board of County Commissioners throughout the State; to the State Chamber of Commerce; and to any and all State, County and Local Officials who may have or should have interest in the subject matter of same, including the Water Conservation Committee of the Resources Development Board of Palm Beach County in West Palm Beach.

R. Y. PATTERSON, Clewiston
HARRISON RAOUL, Shawano
JOHN C. STEPHENS, Ft. Lauderdale
LUTHER JONES, *Chairman*, Belle Glade

RICHARD A. CARRIGAN

1951 — Retired

OFFICERS OF THE SOCIETY

1951

Richard A. Carrigan	President
I. W. Wander	Vice President
W. T. Forsee, Jr.	Member Executive Committee
R. V. Allison	Secretary-Treasurer

APPENDIX

The subsidence of Everglades peat under drainage and cultivation as viewed early in the development of the Everglades Experiment Station. Quotation from Florida Experiment Station Bulletin No. 190, The Stimulation of Plant Response on the Raw, Peat Soils of the Florida Everglades Through the Use of Copper Sulfate and Other Chemicals, p. 80, 1927.

"One of the most important problems from the agricultural standpoint of peat soil in general is that of shrinkage and excessive drying as a result of drainage. If the Everglades is to develop into a durable agricultural project more importance should be placed upon this than any other single consideration.

"In order adequately to protect peat soils against fire and conditions of excessive drought, absolute water control will be necessary and this should be the aim in starting an agricultural development of this nature. In the case of excessive drought, even in the absence of fire, such conditions tend to accelerate natural oxidation processes and result in a further net loss of the material.

"From this standpoint in particular the whole project is not a problem for the engineer alone. It is rather one in which agricultural research must play an important part in developing systems of cropping and rotation that will coordinate with the condition and movement of the water table in such a way as to afford maximum protection against this loss. To those who have a broad, sincere interest in the development of this area as a state resource, the matter of subsidence and water control cannot be over-emphasized. Indeed, we have need but to refer to the experience of the English upon the Fenland of that country where, with time, strata of peat several feet thick have almost disappeared and drainage lines and cultivation are now largely in the clays with which the peat was formerly underlaid. Since the peat soils in the Everglades area are underlaid with limestone rock or by sand over lime rock, the need for caution in their unnecessary exposure is readily seen."

SUBSIDENCE OF ORGANIC SOILS IN THE UPPER EVERGLADES REGION OF FLORIDA

John C Stephens[1] and Lamar Johnson[2]

All organic soils lose surface elevation or subside when drained. This loss apparently continues as long as the lands are drained. The Florida Everglades, which contains the largest known body of organic soils in the world, has lost as much as 6 to 7 feet of soil in the Lake Okeechobee area since 1912. The Fens of England contain deep peat soils which have been under pumped drainage for over 100 years. They have lost approximately one inch per year on the average (1)[3]. In central California, about 200,000 acres of tule peat has been in use for many years with an average recorded loss of approximately two inches per year.

The Everglades originally contained about 2,500,000 acres of organic soils but much of these are now very shallow and the deeper peat which now remains in the Upper Everglades comprises the main body of potential agricultural land in the Everglades area. This soil is particularly valuable for agricultural use and lies within an area containing approximately one thousand square miles, which has been designated as "The Everglades Agricultural Area" in the comprehensive Federal Flood Control plan for Central and Southern Florida. The soils within the boundary of this area have lost approximately forty percent of their original volume in the last forty years since drainage operations began.

In making plans for the original drainage of the Everglades, apparently the main causes of subsidence were misunderstood. The original shrinkage of the peat due to drainage was considered, but the continuing losses by slow oxidation in drained peat were not taken into account. Had the true nature and causes of subsidence losses been fully understood in the earlier days, the original plans might have been modified so as to have saved a large portion of the waste which has occurred since that time.

The United States Department of Agriculture has made continuing studies on the nature and rate of soil subsidence in the Everglades since 1916. From these and other studies the nature of soil subsidence has been more definitely ascertained. The purpose of this report is to sum up progress made to date so that the latest information on the subject will be readily available to those interested in the development of the peat and muck lands in the Upper Everglades area.

These investigations can be divided into three main parts. First, studies were made by running profiles at periodic intervals on established subsidence lines. These studies give the rates of subsidence that have occurred under the existing conditions. Second, studies were made on water table plots under conditions of controlled water levels. These have established the effect of water levels on subsidence losses by oxidation, helped determine the effect of

[1] Research Project Supervisor, Everglades Project, Soil Conservation Service.

[2] Assistant Chief Engineer, of the Central and Southern Florida Flood Control District, and the Everglades Drainage District.

[3] Figures in parentheses refer to "Literature Cited."

different water levels on the growth of various crops, and have established a scale of minimum rates of subsidence which can be expected in cropped lands under conditions of controlled water levels. Third, original levels from early surveys were compiled and compared with more recent surveys to determine the total subsidence loss over the whole of the Upper Everglades area.

These studies show the rate of soil loss depends mostly upon depth to the water table; but, under equivalent conditions of drainage, the virgin peats subside at a slightly higher rate than cultivated peats, and that the undeveloped peat areas in the Upper 'Glades are suffering severe losses. Thus it seems that to insure fullest returns from the remaining soils for the next 50 years, an adequate water control system should be developed for the area as rapidly as practicable that will maintain optimum water levels and make possible the maximum production of food and fiber at minimum subsidence rates.

HISTORY OF SUBSIDENCE STUDIES

In order to secure more definite information on the rate and amount of subsidence of organic soils in Florida following drainage, the United States Department of Agriculture began the location of profile lines over selected peat and muck areas within the State during the year 1915. This work was begun by Charles W. Okey, under the direction of S. H. McCrory, Chief of Drainage Investigations, Bureau of Public Roads. In 1931, drainage investigations were transferred to the Bureau of Agricultural Engineering, and again in 1939 to the Soil Conservation Service following reorganization within the Department of Agriculture. Since 1931, the subsidence investigations have been carried on under the direction of Lewis A. Jones, Chief, Division of Drainage and Water Control, Soil Conservation Service.

Since 1933, subsidence and other studies relative to water control for agricultural lands in the Everglades have been conducted under a cooperative agreement between the Agricultural Experiment Station of the University of Florida and the Soil Conservation Service. In 1949, a Memorandum of Understanding between the Everglades Drainage District, the Central and Southern Florida Flood Control District, the Florida Agricultural Experiment Station, and the Soil Conservation Service was put into effect so that investigations since that date have been made in mutual cooperation with all these agencies.

The first profiles were run over the subsidence lines in 1916 and have been re-run at regular intervals thereafter. Additional lines were later established at the Everglades Experiment Station and around Lake Okeechobee to assist in a more comprehensive study. In April 1936, a mimeographed bulletin (2) describing the results of these studies up until that date was published.

In 1934, water table plots were installed at the Everglades Experiment Station near Belle Glade and the subsidence studies extended on a field where the depth of the water table and other factors could be closely controlled and observed. These investigations continued into 1943 and gave data on subsidence taking into consideration such factors as depth of water table, absence of fire, bacterial activity, soil compaction, soil temperature, and type of culture. In November 1942, a bulletin (3) containing a brief summary on these investigations prior to that date was published by the State Agricultural Experiment Station. These investigations are also described in the various Annual Reports published by the Agricultural Experiment Station of the University of Florida, Gainesville, Florida, and in reports by Clayton (4) and Neller (5).

From early surveys, the elevation of the surface of the Everglades has been obtained prior to any substantial drainage and subsidence. The earliest profiles made across the Everglades were from levels run by the Office of Experiment Station, United States Department of Agriculture. This work began in 1906 when levels were run from Fort Myers up the Caloosahatchee River to Lake Okeechobee. From a point on this survey, an additional line was continued in a southerly direction along the west edge of the Everglades to Brown's Store. Simultaneously, another party ran from Fort Myers southeasterly along the trail to Brown's Store, where the two lines of level were "tied" and the accuracy checked. From Brown's Store a line of levels was continued eastward across the organic soils of the Everglades to a point near Pompano where it connected with another line run from Atlantic tidewater elevation to check the accuracy of the levels. These and other early surveys are described in Senate Document 89 (6). About 1912, levels were run by the Everglades Drainage District along the location of the major drainage canals leading from coastal tidewater to Lake Okeechobee.

A topographic map showing surface elevations was prepared by the Everglades Drainage District compiled from surveys made about 1925. By this time considerable subsidence was found to have occurred along the canals as compared to original conditions in 1912, and the problem of soil loss was already receiving attention from many of those interested in the agriculture of the Everglades (7).

A contour map covering the area of organic soils was prepared by the Soil Conservation Service from topographic surveys made during the period between 1939 to 1942. This map resulted as a part of the intensive investigations made by the Everglades Project of the Soil Conservation Service under a specific appropriation by Congress to conduct research and demonstration work for soil conservation in the Everglades Region. These investigations included topographic surveys, soil conservation surveys to determine the various types of land and their capabilities, and sub-surface investigations of the rock structure and ground water as related to water control in the soil. In connection with the sub-surface investigations, a map showing the approximate contours on the rock surface under the organic soils in the Everglades Region was prepared. These investigations are described in Bulletin 442 (8) published in 1948.

In 1950, profiles and soil soundings were made by the Corps of Engineers over the proposed levee and canal locations in the flood control plan for the Everglades. The recent soil depth and surface elevations for the Everglades Agricultural Area were determined from this work.

By super-imposing surface contour maps prepared from the 1912, 1925, 1940 and 1950 surveys over the rock contour map, the depths of the organic soils in the Upper Everglades was obtained for each date. It was found that the soil losses were greatest near the arterial drainage canals and that in consequence "valleys" had been formed adjacent to them. However, even in areas remote from the immediate drainage influence of the canals, it was found that lands not sufficiently drained for development had nevertheless suffered severe losses. This is presumed to be due to the slow bleeding away of water by the canals as well as the diversion of surplus water in Lake Okeechobee to the Atlantic and Gulf. In early days, the overflow from the Lake drained into the Everglades during wet periods.

The organic soils of the Upper Everglades agricultural area have been divided into four types which have been described in detail in Bulletin 442 (8). These are Okeechobee muck, known locally as "custard apple"; Okeelanta peaty muck, or "willow and elder"; Everglades peaty muck; and Everglades peat, or "sawgrass land."

All the organic soils are dark brown to black in color. They were formed under marsh or swamp conditions by the partial decay of plant materials, with some admixture of mineral material in the case of the muck. Peat consists of 65 percent or more of organic plant remains, with a correspondingly smaller percentage of mineral matter. Muck contains 25 to 65 percent of organic matter mixed with sand, silt, and clay (9). Peaty muck in this area is usually a thin layer of peat over muck, or interstratification of peat and muck as in the instance of Okeelanta peaty muck. The peat and muck soils differ from each other in the kind of plant material from which they were formed, in depth, and in the nature of the underlying material. These soils may rest directly upon limestone or on an intermediate layer of sand or marl. These differences, especially depth of the peat or muck and the characteristics of the immediately underlying material, largely determine the capability of the land for farming and the economic feasibility of the establishment of adequate water control.

Okeechobee muck is a nearly black mixture of organic material and fine mineral soil that may be as much as 4 feet deep, underlain by brown fibrous peat. Deeper alternations of peat and muck layers may be present. An area of approximately 32,000 acres of this type soil is contained within the Everglades agricultural area occupying a belt surrounding the eastern and southeastern margin of Lake Okeechobee. This soil supported an original growth of custard apple trees, hence, the local name of "custard apple muck" for the soil type. It was early recognized as the best of the soils in the area and supported the earliest agriculture around the Lake. The organic portion of the soil appears to have been formed from the remains of succulent aquatic water plants which commonly grow in deep water, while the mineral content is probably due to its close proximity to the Lake and the deposition of fine sediment during overflows. The ash or mineral content varies from 35 to 70 percent of the oven-dry weight and the density is higher than the other organic soils in the area.

Okeelanta peaty muck consists of 6 to 18 inches of finely fibrous, well decomposed organic matter over a layer of black plastic muck which contains from 15 to 35 percent of mineral matter, and resembles Okeechobee muck. It borders the Okeechobee muck on the south and east and originally supported a growth of willows and elders. There are approximately 26,000 acres of this soil types within the area. It lies directly over hard limestone and most if it is still over 5 feet deep. In many areas cultivation has now entered into the top plastic layer.

Everglades peaty muck contains somewhat less mineral material than Okeelanta peaty muck or from 10 to 15 percent. It is usually lacking in the sub-surface layer of black plastic muck and the surface layer rests on brown, fibrous felty peat, although some of it grades towards Okeelanta peaty muck. The total area is approximately 35,000 acres of which nearly one-third is underlain by sand.

By far the most extensive type of organic soil in the area is Everglades peat, the soil of the broad sawgrass plains, which occupies approximately 540,000 acres within the Everglades Agricultural Area. The upper 6 to 18 inches is an almost black, finely fibrous peat which contains from 8 to 15 percent mineral matter. The subsoil is a brown, undecomposed, finely fibrous peat which rests on the underlying rock, sand, or marl. It has been formed mainly from sawgrass material. Originally the entire profile was a brown, fibrous mass in which the partially decomposed sawgrass roots were readily distinguished. The roots are predominantly aligned in a vertical position which results in a soil structure that permits rapid movement of water vertically but more slowly laterally. After drainage the exposed layer becomes oxidized and weathered which gradually transforms the top soil into a black oxidized condition. When cultivated, the top layer changes into an amorphous mass, the density increases, the color darkens, the seepage rate decreases, and the top soil is transformed into a mucky condition. The saturated peat is slightly heavier than water, and when drained the water retained is equal to approximately three-fourths the total weight of the field sample. After a period of cultivation the density of the upper 18 inch layer of the soil will approximately double that of the underlying material; the oven-dry weight increasing from about 8 lbs. to 16 lbs. per cubic foot. This increase in density is accompanied by a corresponding decrease in volume; however, in subsidence of this nature there is little loss of actual soil material; the loss in surface elevation being due to compaction and structural change.

Northeast of West Palm Beach Canal from Lake Okeechobee to Twenty-Mile Bend is an old slough in which the peat is believed to have been originally formed partly from water plants and was of a less dense structure than the Everglades peat. However, as a result of partial drainage for a number of years, it has become denser and can scarcely be distinguished from Everglades peat. The deepest soils in the area occur along this old slough.

CAUSES OF SUBSIDENCE

Loss of surface elevation or subsidence accompanying drainage of organic soils in the Everglades is due mainly to slow oxidation from biochemical action, to burning, and to mechanical compaction. Minor losses have occurred from shrinkage due to drying and loss of the buoyant force of water in the drained layer. Wind and water erosion has had little effect in this region.

The most serious and continuing loss is due to slow oxidation caused by the action of aerobic bacteria. These organisms are active only in the aerated zone and the rate at which the soil subsides due to their action depends primarily upon the depth to the water table; hence the higher the water table, the less this loss. Such bacteria belong to the saphrophytes which live on dead or decaying organic matter and begin their assault upon the peat when the water level falls appreciably below the surface. In the presence of oxygen they convert the organic matter into carbon dioxide gas. This gas has been collected and measurements show that the amount of gas evolved from the peat soil was directly related to the rate of loss of soil mass (10). Temperatures seem to regulate the activity of the bacteria and it appears that the subtropical climate of the Everglades increases the rate of soil loss as compared to losses for organic soils in the northern states under conditions of similar drainage. There also seems to be little doubt that the rate of oxidation is related to the amount of air movement within the drained zone. It has been noted that whenever the soil surfaces are sealed in the peat soils, the subsidence materially decreases. Thus, paved roadways and concrete tennis courts

in the Everglades which have been constructed for a period of 10 years or more now stand a foot or more higher than the immediately surrounding lands.

Loss in elevation is most rapid during the first five years following drainage and cultivation. The virgin Everglades peat is about the same density from top to bottom prior to drainage, but after 10 years of farming the top 18 inches increases in density to about double that of the peat beneath. A large part of this loss is due to compaction during farming operations. If virgin peat is drained but not put to use, the samples taken from these unused lands show the top aerated zone has developed a spongy texture and there has been an actual loss of soil mass greater than that on adjacent farmed areas (11). Whenever such land is later put to cultivation the loss in soil mass and in depth is greater than the adjacent farmed area provided they have had equal drainage. Thus, peat lands once drained should be put to use as soon as possible to achieve the maximum potential production and benefits.

Soils in the Everglades are also destroyed by burning. Loss from fire is more spectacular and arouses public interest far more than the loss caused by natural oxidation; yet, in the long run, the relentless toll of the invisible hosts of organisms results in a much greater total soil loss than from fire. Sawgrass fires sweep over the undeveloped 'Glades almost annually. They do little permanent soil damage until dry periods when the water table sinks from 18 to 24 inches or more below ground and the peat becomes dry enough to burn. Once this occurs, the heat of combustion dries out the moisture from adjacent soils and they become very difficult to extinguish. In the more remote areas of the Everglades they may reach such proportions as to defy man's attempts to control them and continue to burn until heavy rains occur. In farmed lands, and accessible locations, such fires are usually discovered early and extinguished before they can do much damage.

"Blowing", or the removal of soil by wind erosion, which may be serious in other localities, accounts for practically no soil loss in the Everglades region since this area is so large that soil blown from one field is simply deposited on surrounding fields.

SUBSIDENCE LINE STUDIES

The following graphs with the accompanying descriptions have been prepared from information obtained by periodic leveling over the various profile lines and show the lowering of ground surface with respect to time. In these cases it is impossible to determine what portion of the total loss is due to each of the causes mentioned in the preceding discussion, but it appears certain that slow oxidation of the drained peat was the principal cause. Some elevations of the water table were obtained but the average elevations and fluctuations are not known. The results show only the total losses from all causes.

Figure 1. (Line 280 ft. north of Bolles Canal at Okeelanta.)

This line is located in an area in which the soil is predominantly Okeelanta peaty muck and had gravity drainage prior to 1942 at which time pumps were installed. The west half of the line was in fallow prior to 1936 while the east half was in cultivation from one to three year periods prior to 1922. Sporadic plantings of truck crop followed the installation of pumps in 1942 until the present. This area has been burned over several times, but a comparison of land surface elevations with adjacent unburned lands shows that the loss in elevation due to fires is only a small part of the total loss in elevation

This line shows the relative rapid initial subsidence, the decreasing rate under gravity drainage as the ground surface sank and drainage was impaired, and the consequent increase in subsidence rates after the installation of pumps in 1942.

Figure 2. (Line below South Bay locks near One-Mile Post on North New River Canal.)

This line is located in an area in which the soil is Okeelanta peaty muck and had gravity drainage prior to the installation of pumps in 1927 by the South Florida Conservancy District. The land in this area was not used for crops until after the installation of pumps. Since that date, it has been generally planted to cane and truck crops. The normal pattern of very fast sinking of the surface with initial drainage, a leveling off as gravity drainage decreased, the increase in rate with increased drainage due to pumping installations, and the steady loss of surface elevation thereafter is seen.

Figure 3. (Line near south shore of Lake Okeechobee at South Bay.)

This line is located in Everglades peaty muck and had gravity drainage prior to 1927 at which time pumps for the area were installed by the South Florida Conservancy District. Approximately half of this line was in cultivation from 1914 to 1928, and nearly all of the area traversed by the line has been in cane and truck crops since 1927. As far as is known, none of the land in this area has ever been seriously burned. The early initial subsidence loss, the leveling out period during the latter phase of gravity drainage, the increase in subsidence due to pump drainage, and the relatively consistent losses afterward are illustrated by this line.

Figure 4. (Line on lawn at Experiment Station 85 ft. east of pump ditch. Station 0 + 50 to 3 + 50.)

This line is located at the Everglades Experiment Station on Everglades peat covered with a thick sod of St. Augustine grass and has had controlled drainage for the entire period of observation. The area was covered with grass approximately 14 years prior to establishment of the subsidence line. It has not been compacted by grazing or rolling, and soil samples show that a spongy, open textured structure has developed in the aerated zone. Loss of soil mass has therefore been more than that indicated by loss of surface elevation as shown on the graph.

Figure 5. (Line on lawn at Experiment Station 95 ft. west of front porches on residences. Station 1 + 75 to 6 + 25.)

This line is located on Everglades peat covered with a thick sod of St. Augustine grass and has had controlled drainage for the entire period of observation. This area was also covered with grass for approximately 14 years prior to establishment of the subsidence line. For all practical purposes, this line duplicates that shown in Figure 4, and density samples show the same open, spongy texture as described for that line.

Figure 6. (Well line "H" at Experiment Station. Station 0 + 00 to 4 + 75, exclusive of ditch banks.)

This line is located at the Everglades Experiment Station on Everglades peat. The northern half has been in pasture and the southern half generally planted to truck crops. The area has had controlled drainage for the period of observation and had been planted to truck crops for approximately 14 years prior to establishment of the subsidence line. The water table for this line has been comparable to that for the lines shown in Figures 4 and 5. It should be noted

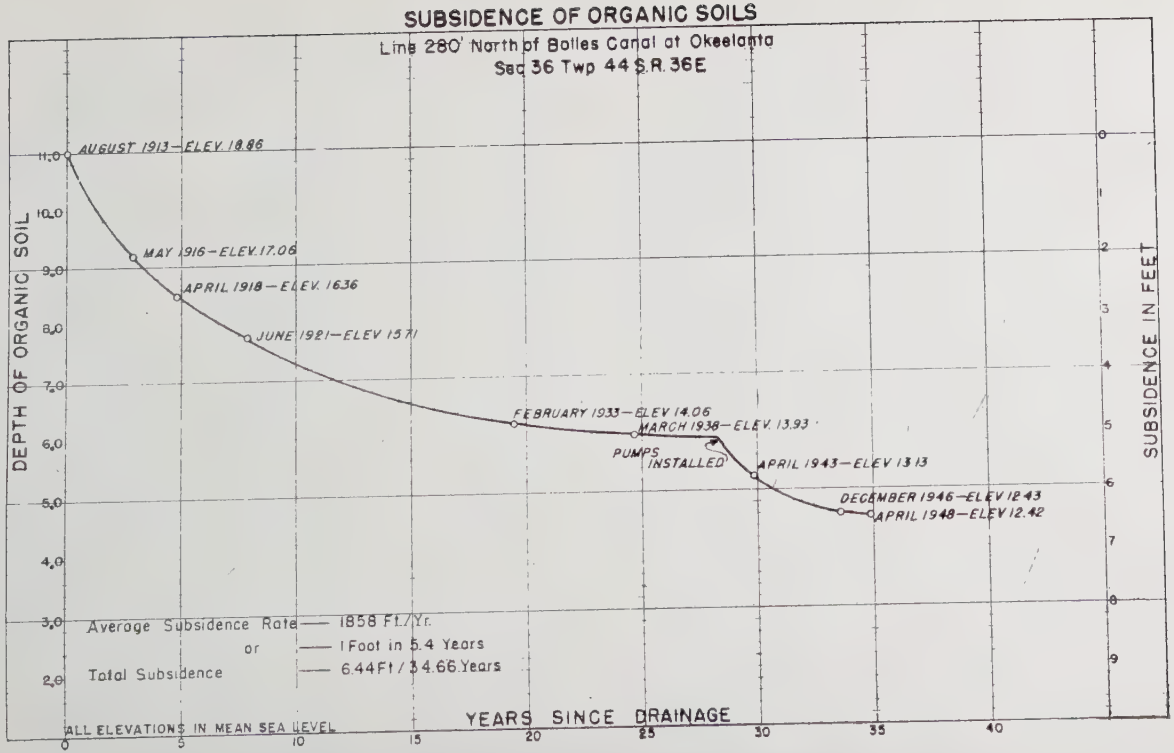

SUBSIDENCE OF ORGANIC SOILS
Line 280' North of Bolles Canal at Okeelanta
Sec 36 Twp 44 S.R. 36E
AUGUST 1913—ELEV. 18.86
MAY 1916—ELEV. 17.06
APRIL 1918—ELEV. 16.36
JUNE 1921—ELEV 15.71
FEBRUARY 1933—ELEV 14.06
MARCH 1938—ELEV. 13.93
PUMPS INSTALLED
APRIL 1943—ELEV 13.13
DECEMBER 1946—ELEV 12.43
APRIL 1948—ELEV 12.42
DEPTH OF ORGANIC SOIL
SUBSIDENCE IN FEET
Average Subsidence Rate — 1.858 Ft./Yr.
or — 1 Foot in 5.4 Years
Total Subsidence — 6.44 Ft. / 34.66 Years
ALL ELEVATIONS IN MEAN SEA LEVEL
YEARS SINCE DRAINAGE

Figure 1. Showing the relative rapid initial subsidence, the decreasing rate under gravity drainage as the ground surface sank and drainage was impaired, and the consequent increase in subsidence rates after pumped drainage on Okeelanta peaty muck.

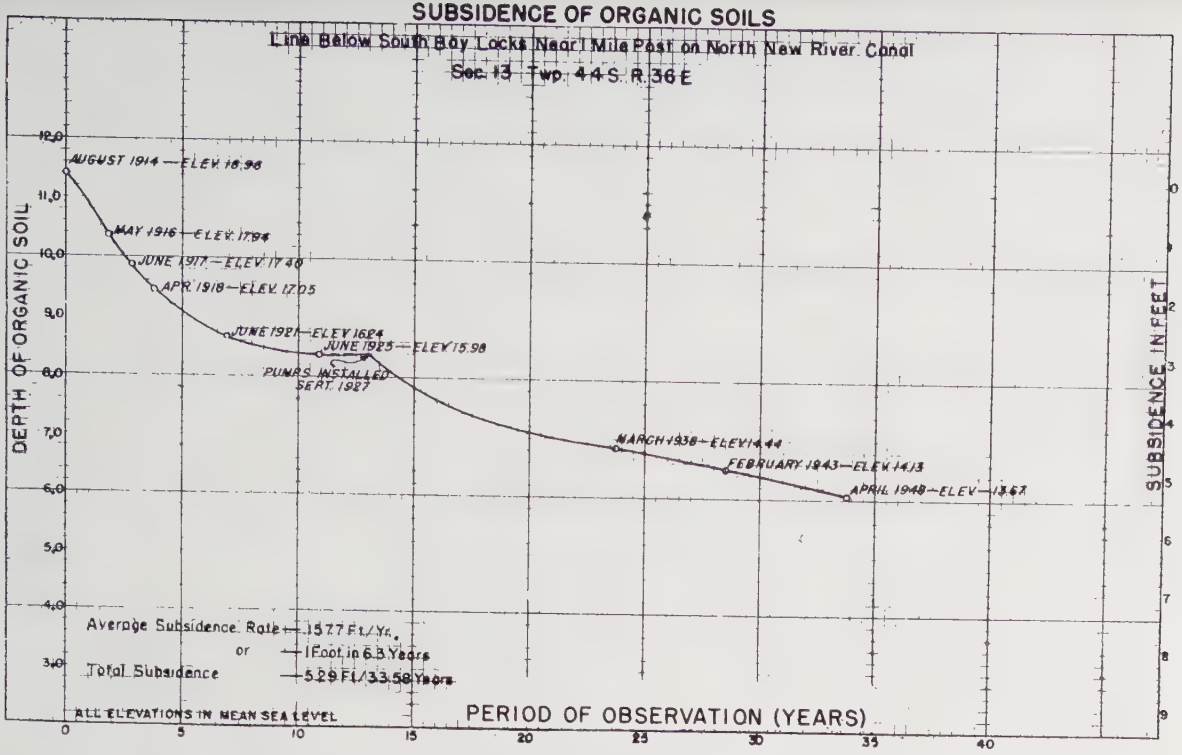


Figure 2. The normal pattern of fast sinking of the surface with initial drainage, a leveling off as gravity drainage decreases, an increase in rate with increased drainage due to pumping, and the steady loss of surface elevation thereafter is seen. Soil is Okeelanta peaty muck.

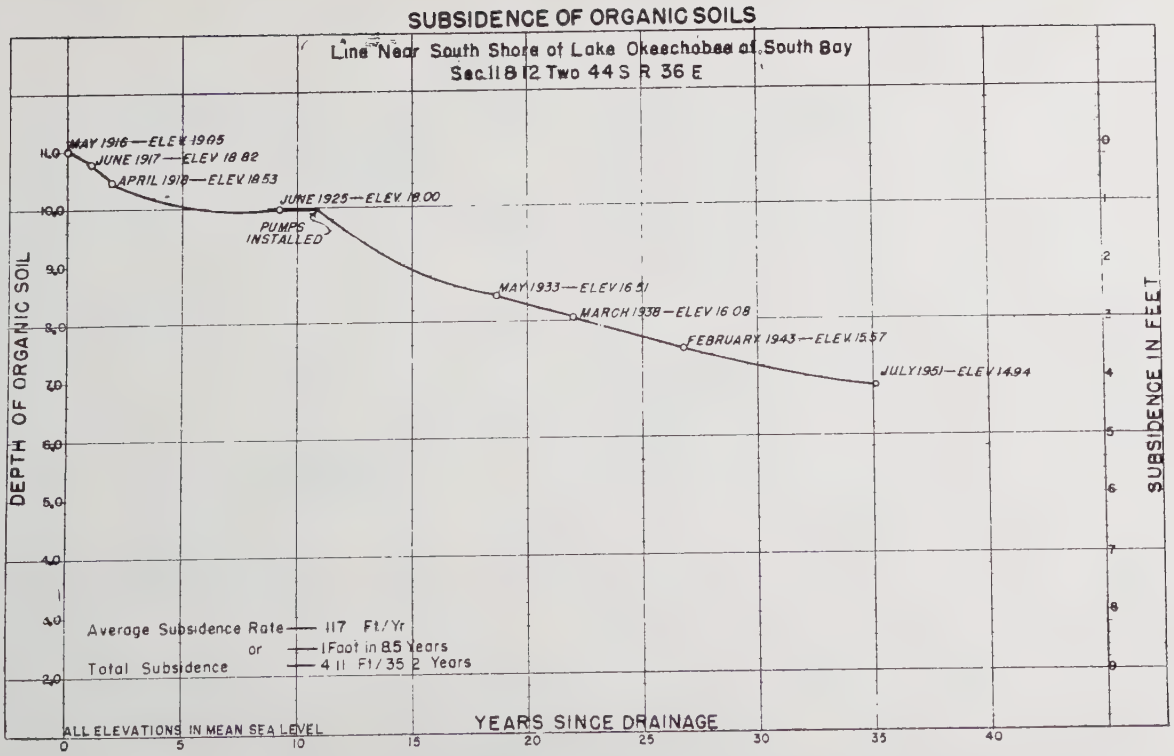

SUBSIDENCE OF ORGANIC SOILS
Line Near South Shore of Lake Okeechobee at South Bay
Sec. 11 & 12 Two 44 S R 36 E
MAY 1916 — ELEV 19.05
JUNE 1917 — ELEV 18.82
APRIL 1918 — ELEV 18.53
JUNE 1925 — ELEV 18.00
PUMPS INSTALLED
MAY 1933 — ELEV 16.51
MARCH 1938 — ELEV 16.08
FEBRUARY 1943 — ELEV 15.57
JULY 1951 — ELEV 14.94
DEPTH OF ORGANIC SOIL
SUBSIDENCE IN FEET
Average Subsidence Rate — .117 Ft./Yr
or — 1 Foot in 8.5 Years
Total Subsidence — 4.11 Ft./35.2 Years
ALL ELEVATIONS IN MEAN SEA LEVEL
YEARS SINCE DRAINAGE

Figure 3. The normal subsidence pattern is again illustrated by this graph. Soil is Everglades peaty muck. As far as is known, none of the land in this area has ever been seriously burned.

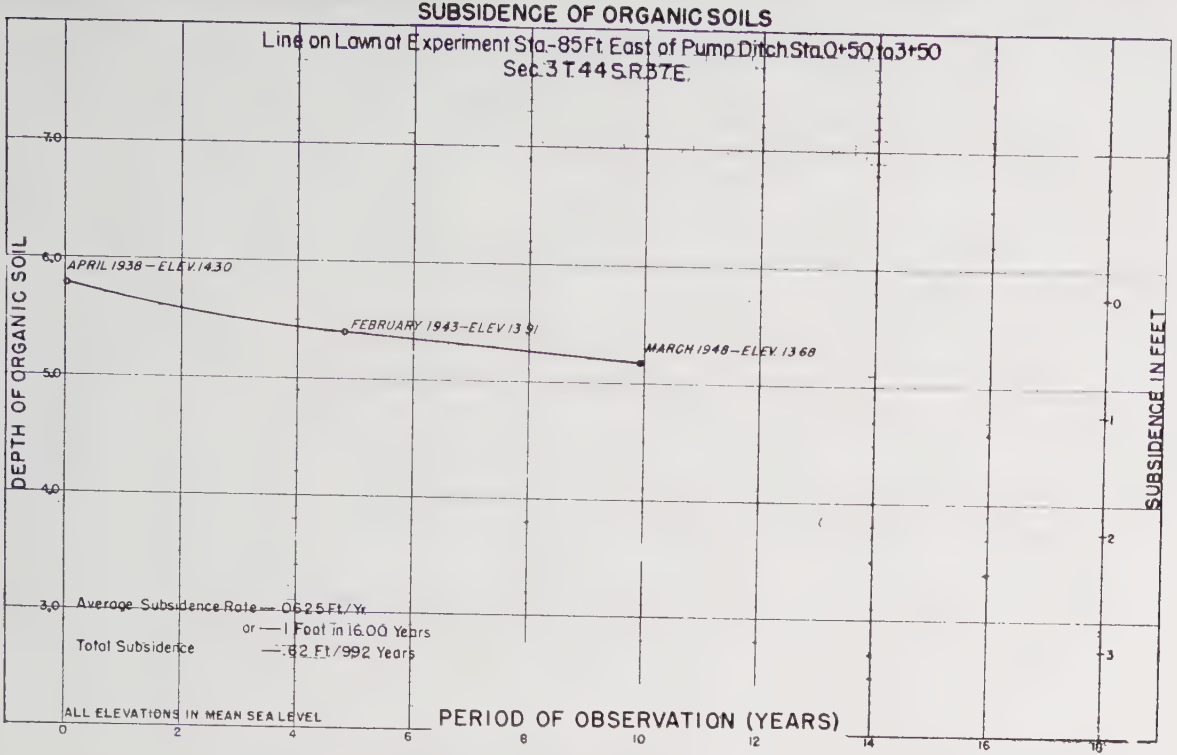

SUBSIDENCE OF ORGANIC SOILS
Line on Lawn at Experiment Sta.-85 Ft. East of Pump Ditch Sta.0+50 to 3+50
Sec. 3 T. 44 S. R. 37 E.
DEPTH OF ORGANIC SOIL
SUBSIDENCE IN FEET
APRIL 1938 – ELEV. 14.30
FEBRUARY 1943 – ELEV. 13.91
MARCH 1948 – ELEV. 13.68
Average Subsidence Rate — 0.625 Ft./Yr.
or — 1 Foot in 16.00 Years
Total Subsidence — 3.2 Ft./99.2 Years
ALL ELEVATIONS IN MEAN SEA LEVEL
PERIOD OF OBSERVATION (YEARS)

Figure 4. Subsidence on ungrazed sod. Soil samples taken in the upper layer show that a spongy, open textured layer has developed in the drained zone with considerable loss of soil mass.

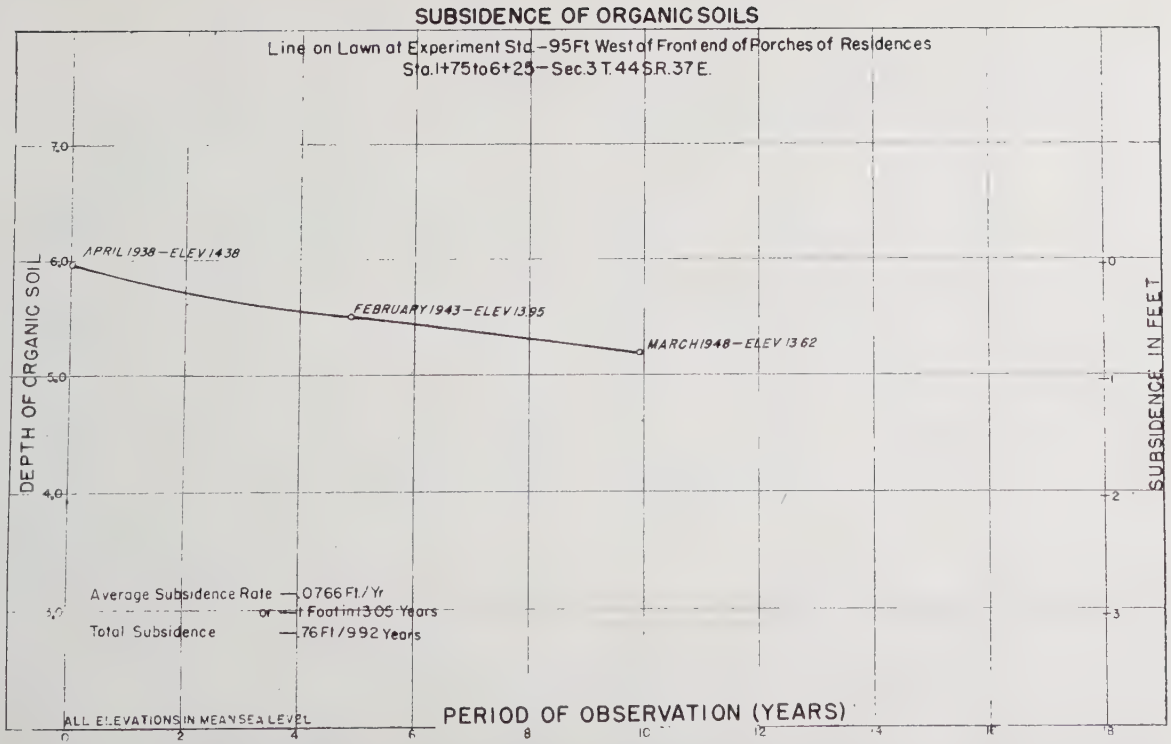

SUBSIDENCE OF ORGANIC SOILS
Line on Lawn at Experiment Std.–95Ft West of Front end of Porches of Residences
Sta.1+75to6+25–Sec.3 T.44S R.37E.
APRIL 1938–ELEV 1438
FEBRUARY 1943–ELEV 13.95
MARCH 1948–ELEV 13.62
DEPTH OF ORGANIC SOIL
SUBSIDENCE IN FEET
Average Subsidence Rate — 0766 Ft./Yr
or — 1 Foot in 13.05 Years
Total Subsidence — 76 Ft / 992 Years
ALL ELEVATIONS IN MEAN SEA LEVEL
PERIOD OF OBSERVATION (YEARS)

Figure 5. This line, for all practical purposes, duplicates that shown in Figure 4. Density samples show the same spongy texture. There are some indications that subsidence rates on sod lands are reduced by grazing and compaction of the surface.

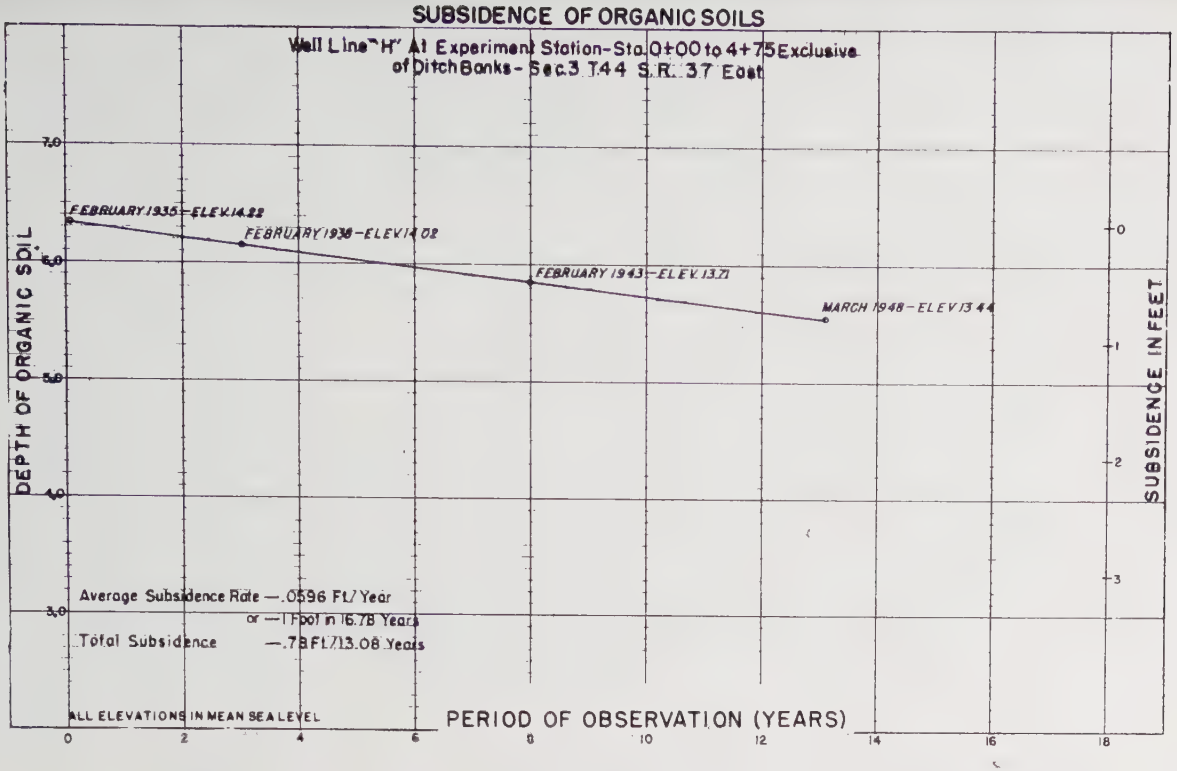

SUBSIDENCE OF ORGANIC SOILS
Well Line "H" At Experiment Station-Sta. 0+00 to 4+75 Exclusive of Ditch Banks - Sec. 3 T.44 S.R. 37 East
FEBRUARY 1935 - ELEV. 14.22
FEBRUARY 1938 - ELEV. 14.02
FEBRUARY 1943 - ELEV. 13.71
MARCH 1948 - ELEV. 13.44
DEPTH OF ORGANIC SOIL
SUBSIDENCE IN FEET
Average Subsidence Rate — .0596 Ft./Year
or — 1 Foot in 16.78 Years
Total Subsidence — .78 Ft. / 13.08 Years
ALL ELEVATIONS IN MEAN SEA LEVEL
PERIOD OF OBSERVATION (YEARS)

Figure 6. The water table for this line has been comparable to that of the two previous lines. However, this land has been in truck crops and pasture. Soil samples show that loss of soil mass is less than from the ungrazed sod areas.

that the average subsidence rate along this line is slightly lower than for the two previous lawn lines. Further, the soil samples from this line showed increased density in comparison to these lines. The sealing effect of cultivation on the cropped lands has apparently decreased the rate of loss of soil mass as compared to the uncultivated areas.

Figure 7. (Well line "A" at Experiment Station.)

This line is located in Section 10 at the Everglades Experiment Station on Everglades peat with virgin growth prior to 1940. The area received only fair drainage by perimeter ditches until 1940 when small farm laterals were dug. The south half, or Reach "A", has been undeveloped and in sawgrass and elders during the period of observation. The area traversed by the north half of this line, or Reach "B", was undeveloped until January 1944 when it was planted and disced. Lateral drainage ditches were dug in January 1945. The steady rate of subsidence along Reach "A" and the increased rate of subsidence along Reach "B" due to cultivation is illustrated by this line.

Figure 8. (East line at Experiment Station.)

This line is located on Everglades peat at the Everglades Experiment Station and was originally established in 1927, but original notes were lost. The line as reestablished in 1934 is representative of land that has had its initial subsidence from cultivation and drainage. It has been planted continuously to truck crops with controlled drainage for the period of observation, and possibly represents average subsidence conditions that prevail on lands planted to truck crops in the Everglades where flood fallow is not practiced.

Figure 9a. (Wedgeworth-Raoul Farms - North and South line. Station 0 + 00 to Station 9 + 90.)

This line is laid out at right angles to drainage laterals on Everglades peat soil that was in virgin sawgrass until 1938. The area was plowed, disced and in cultivation from 1938 through November 1940. The area was converted to pasture between 1940 and 1943 and was in pasture through 1948.

Figure 9b. (Wedgeworth-Raoul Farms - North and South line. Station 11 + 00 to 20 + 00.)

This line is at right angles to drainage laterals on Everglades peat soil that was in sawgrass until 1937. The area was cultivated intensively for truck crops (celery and beans) through 1948.

Figure 9c. (Wedgeworth-Raoul Farms - East and West line. Station 0 + 00 to 9 + 50.)

This line is located on Everglades peat soils that was in virgin sawgrass until 1938. The area was plowed, disced and brought into cultivation with a fair degree of drainage from 1938 through November 1940. The area was converted to pasture between 1940 and 1943 and was in pasture through 1948.

Figure 9d. (Wedgeworth-Raoul Farms - Station 10 + 50 to 23 + 00.)

This line is located on Everglades peat soil that was under sawgrass with moderate drainage until 1937. The area was put into cultivation in 1937 for potatoes; in 1938 for potatoes and gladiolus; for celery in 1939; for celery and spring crop beans in 1940 to 1946; and was idle from 1946 to 1947. The

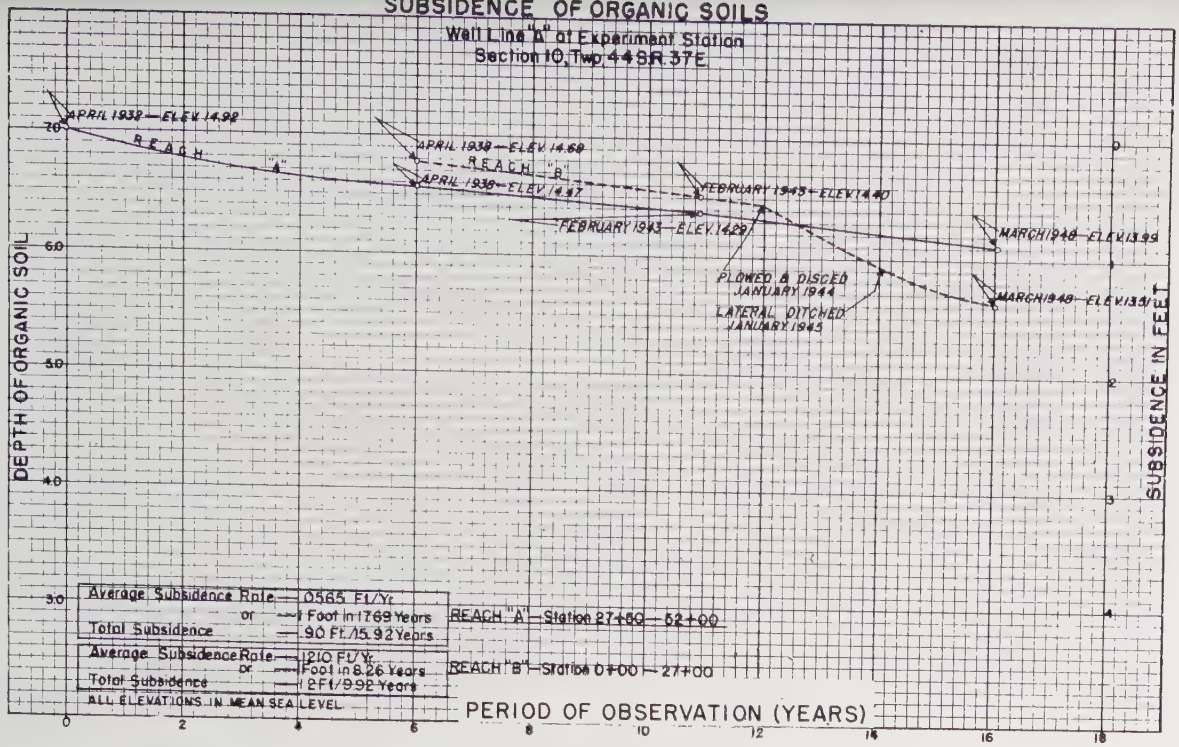

SUBSIDENCE OF ORGANIC SOILS
Well Line "A" at Experiment Station
Section 10, Twp 44 SR 37E
APRIL 1938 — ELEV 14.98
REACH "A"
APRIL 1938 — ELEV 14.68
REACH "B"
APRIL 1938 — ELEV 14.47
FEBRUARY 1943 — ELEV 14.40
FEBRUARY 1943 — ELEV 14.29
MARCH 1948 — ELEV 13.95
MARCH 1949 — ELEV 13.91
PLOWED & DISCED JANUARY 1944
LATERAL DITCHED JANUARY 1945
DEPTH OF ORGANIC SOIL
SUBSIDENCE IN FEET
PERIOD OF OBSERVATION (YEARS)
Average Subsidence Rate — .0565 Ft/Yr
or — 1 Foot in 17.69 Years
Total Subsidence — .90 Ft. /15.92 Years
REACH "A" — Station 27+60 — 52+00
Average Subsidence Rate — .1210 Ft/Yr.
or — 1 Foot in 8.26 Years
Total Subsidence — 2 Ft/9.92 Years
REACH "B" — Station 0+00 — 27+00
ALL ELEVATIONS IN MEAN SEA LEVEL

Figure 7. Reach "A" of this line has remained undeveloped and in sawgrass during the period of observation. Reach "B", the north half of this line, was undeveloped until 1944 when it was planted and disced. The steady rate of subsidence along Reach "A" and the increased rate of subsidence along Reach "B" due to initial cultivation is illustrated.

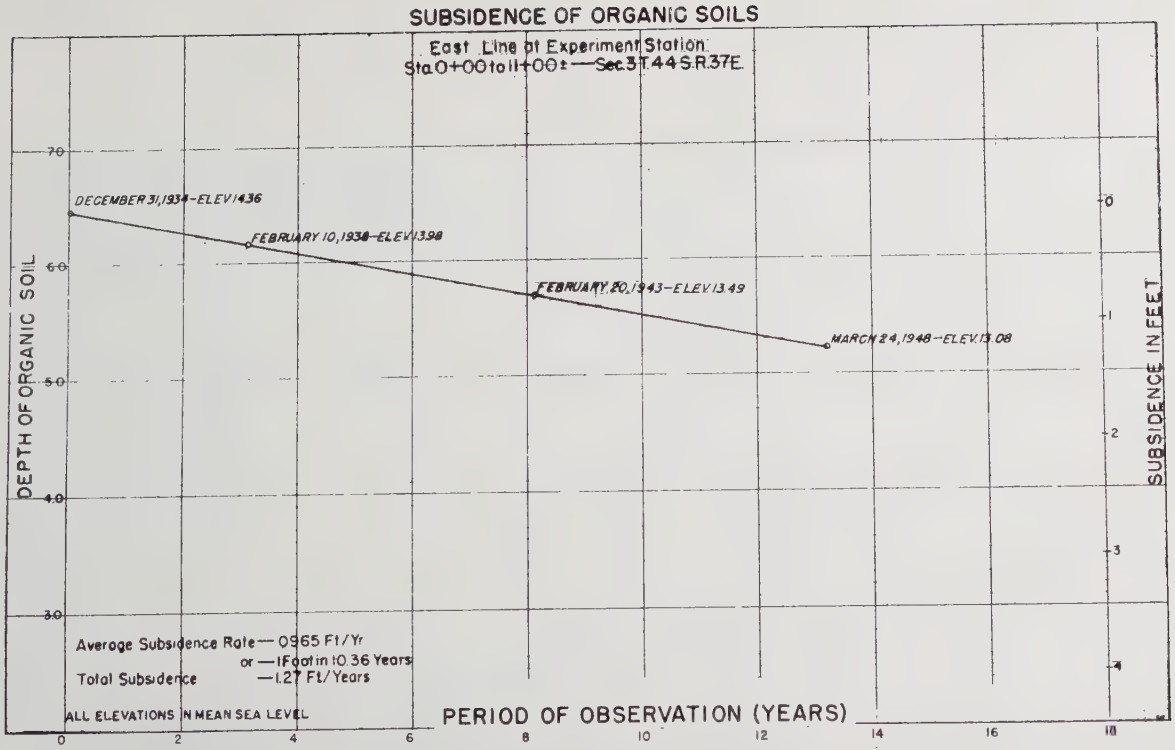

SUBSIDENCE OF ORGANIC SOILS
East Line of Experiment Station
Sta 0+00 to 11+00± — Sec 3 T 44 S R 37 E
DECEMBER 31, 1934 – ELEV 14.36
FEBRUARY 10, 1938 – ELEV 13.98
FEBRUARY 20, 1943 – ELEV 13.49
MARCH 24, 1948 – ELEV 13.08
DEPTH OF ORGANIC SOIL
SUBSIDENCE IN FEET
PERIOD OF OBSERVATION (YEARS)
Average Subsidence Rate — 0.965 Ft/Yr
or — 1 Foot in 10.36 Years
Total Subsidence — 1.27 Ft/Years
ALL ELEVATIONS IN MEAN SEA LEVEL

Figure 8. This graph is representative of subsidence on land that has already taken its initial loss from mechanical compaction. This field has been planted to truck crops with controlled drainage at the Everglades Experiment Station since before 1934. The rate of subsidence has been

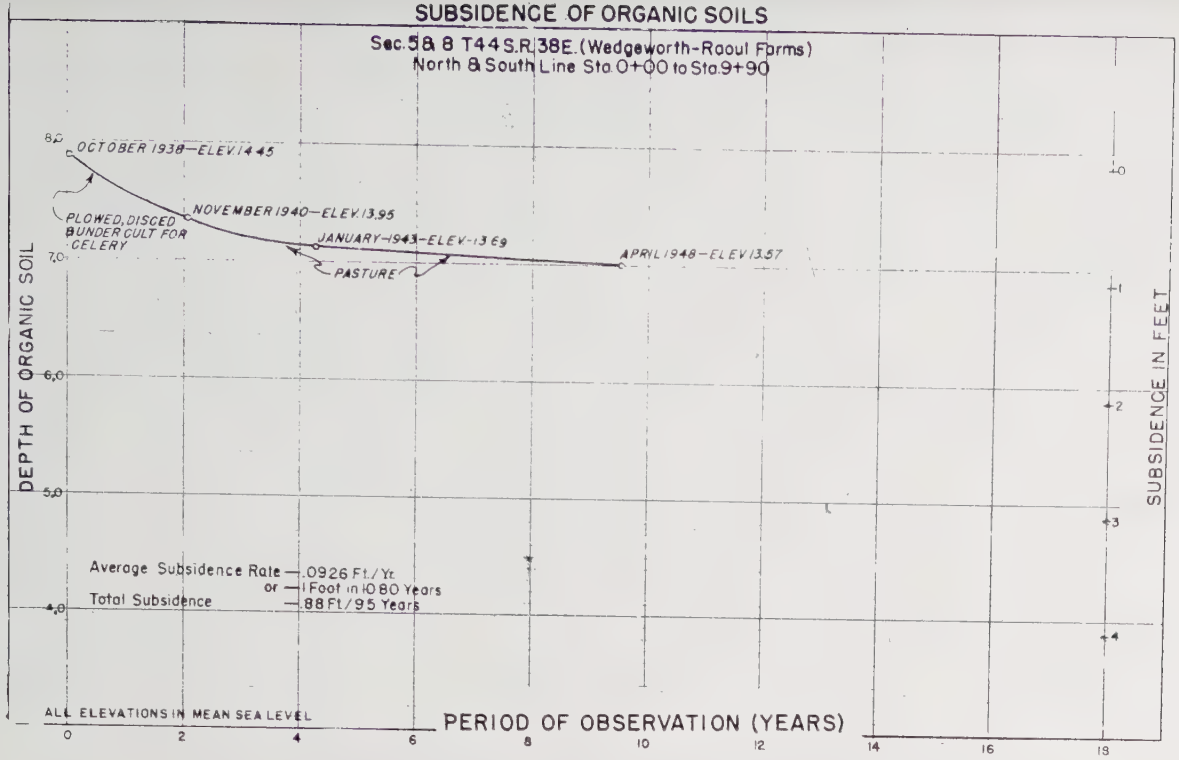

SUBSIDENCE OF ORGANIC SOILS
Sec. 5 & 8 T44S.R.38E. (Wedgeworth-Raoul Farms)
North & South Line Sta. 0+00 to Sta. 9+90
OCTOBER 1938—ELEV. 14.45
NOVEMBER 1940—ELEV. 13.95
JANUARY-1943—ELEV-13.69
APRIL 1948—ELEV. 13.57
PLOWED, DISCED & UNDER CULT FOR CELERY
PASTURE
DEPTH OF ORGANIC SOIL
SUBSIDENCE IN FEET
Average Subsidence Rate — .0926 Ft./Yr.
or — 1 Foot in 10.80 Years
Total Subsidence — .88 Ft./ 95 Years
ALL ELEVATIONS IN MEAN SEA LEVEL
PERIOD OF OBSERVATION (YEARS)

Figure 9a. The following group of figures are significant in that they indicate that peat land in grazed pasture may subside slower than for similarly drained lands under other culture. Compare figures 9a with 9b, and 9c with 9d.

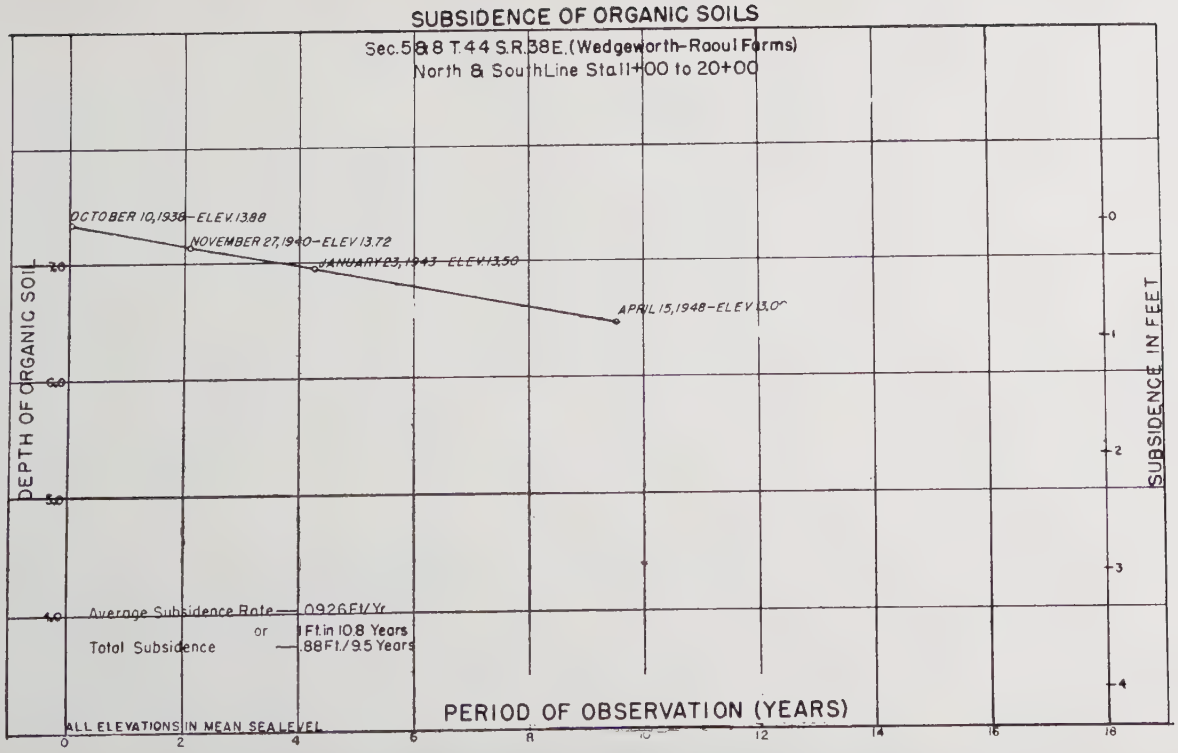


Figure 9b. This land adjoins that represented in 9a but has been in truck crops continuously through 1948; whereas the other area was converted to pasture between 1940 and 1943 and remained so through 1948.

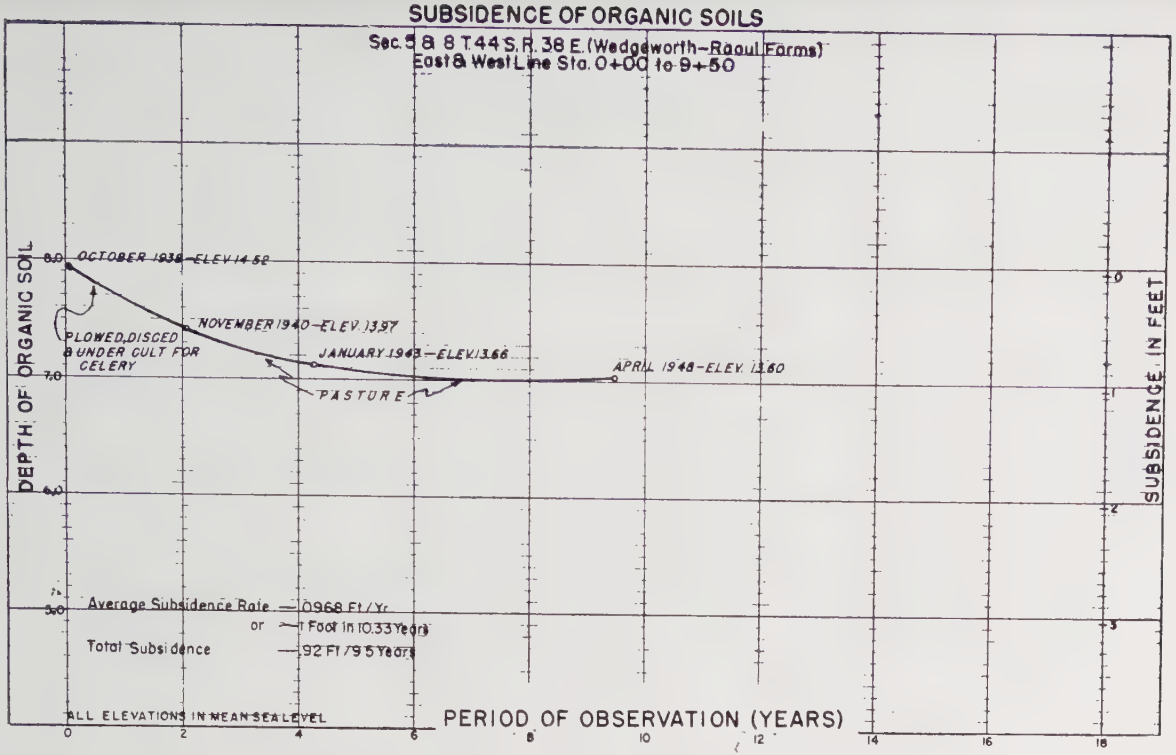

SUBSIDENCE OF ORGANIC SOILS
Sec. 5 & 8 T.44 S. R. 38 E. (Wedgeworth–Raoul Farms)
East & West Line Sta. 0+00 to 9+50
DEPTH OF ORGANIC SOIL
SUBSIDENCE IN FEET
OCTOBER 1938 – ELEV. 14.52
NOVEMBER 1940 – ELEV. 13.97
JANUARY 1943 – ELEV. 13.66
APRIL 1948 – ELEV. 13.60
PLOWED, DISCED & UNDER CULT FOR CELERY
PASTURE
Average Subsidence Rate — .0968 Ft./Yr.
or — 1 Foot in 10.33 Years
Total Subsidence — .92 Ft. / 9.5 Years
ALL ELEVATIONS IN MEAN SEA LEVEL
PERIOD OF OBSERVATION (YEARS)

Figure 9c. This land was converted to pasture with a decrease in subsidence rate indicated thereafter. The adjoining land, Figure 9d, was kept in truck and subsidence continued at a steady rate.

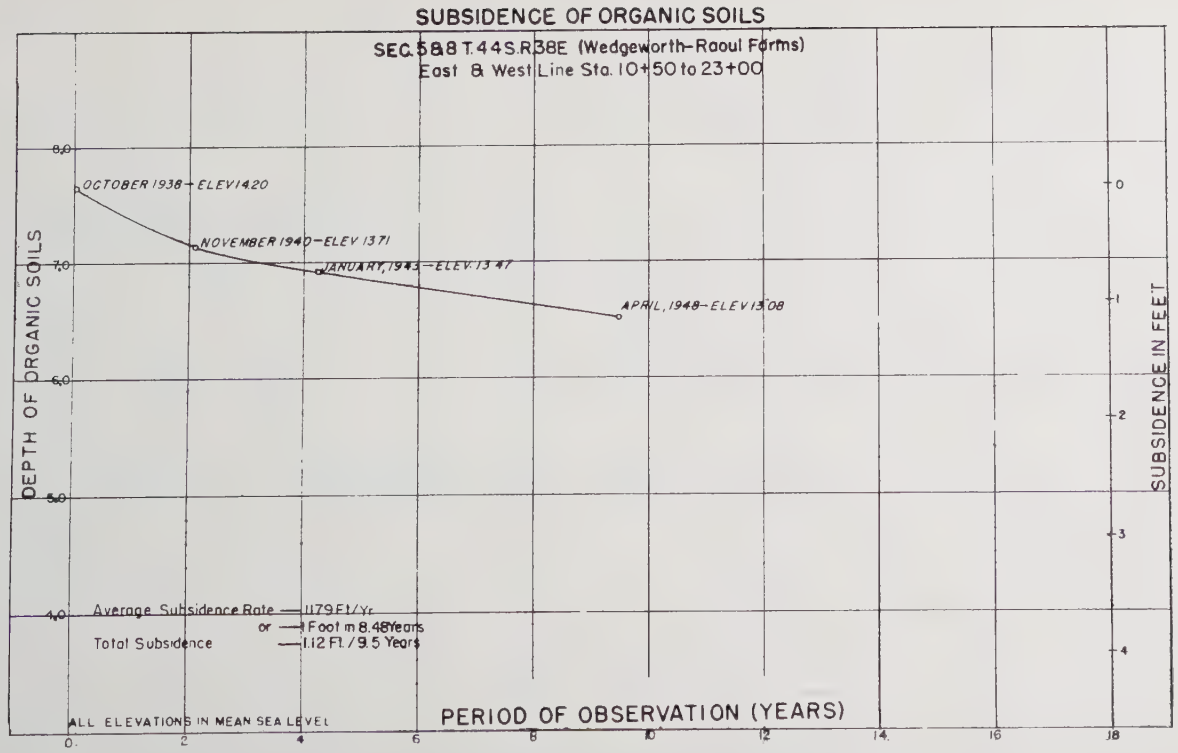


Figure 9d. The period of observation on the preceding group of lines has been too short and density tests have not been made so there is as yet insufficient data to judge whether or not these grazed pasture lands will continue to subside at slower rates than the other lands.

area was in native grass pasture lightly grazed from 1947 to present. Compare Figures 9a against 9b, and 9c against 9d. It will be noted that when Lines "A" and "C" were put into pasture and grazed, the subsidence rate decreased materially as compared to the adjacent reach which was in truck crops. However, the period of observation has been too short and density tests have not been made so that there is as yet insufficient data to judge whether or not this type culture may offer an effective means of reducing subsidence rates any appreciable extent.

Figure 10. (Well Line "I" at Liberty Point.)

This line is located on Everglades peaty muck and the area it traverses had its initial subsidence prior to beginning of observation. This line is believed representative of cane land with average water control.

Figure 11. (Line "D" at Davie, Florida.)

This line is located near Davie, Florida and was laid out on Everglades peat over sand. The area received drainage by one of the first pumping stations installed in the Everglades Region in 1913. Pumping was discontinued by the old Davie District about 1916. The completion of the Danie Cut-off Canal shortly thereafter furnished sufficient gravity drainage, and in 1920 this area was incorporated into the present Broward Drainage District. From Station 14 + 00 to 70 + 00 all but 900 feet has been in cultivation for one or more seasons. Since 1933, approximately 1,000 feet of the line has been embraced within an orange grove. From Station 0 + 00 to 14 + 00, the line has been covered by a school yard and an abandoned orange grove,,and in many places along this portion of the line, there are now areas of bare sand. While not in the Everglades Agricultural Area, this line is shown because it illustrates the fact that the subsidence of peat continues under drainage until the underlying material is reached.

EXPERIMENTAL STUDIES ON CONTROLLED WATER TABLE PLOTS

In 1934 at the Everglades Experiment Station, a field of Everglades peat was divided into eight blocks, each 100 x 240 feet. These blocks were surrounded by a system of ditches and check dams whereby the water table could be controlled at any desired level under each block. This was accomplished by means of two 1,000 gpm electrically driven pumps with automatic float controls which pumped the water from the block of the lowest water table to that of the highest, from where it passed successively over check dams to each of the lower levels. Both mole drains and tile drains were provided to aid in keeping levels as uniform as possible under each block. Overhead spray irrigation was installed on two of the blocks to supply water by this method during dry seasons. A ground water observation well and a recording ground water gage, connected by underground tubing, were installed on each block. Figure 12 is a plan drawing showing the arrangement and layout of the water table field. Each block was subdivided into three equal divisions, and planted to different crops, as shown on plots 4 and 5, Figure.12.

In 1934, the blocks were uniformly cropped and the water level held at the same level under all blocks to determine field variability. Precise levels were run over the entire field to obtain the average ground elevation of each block and the adjacent area. The prescribed water levels were established in November 1935.

The purpose of these experiments was to determine the effect of the water

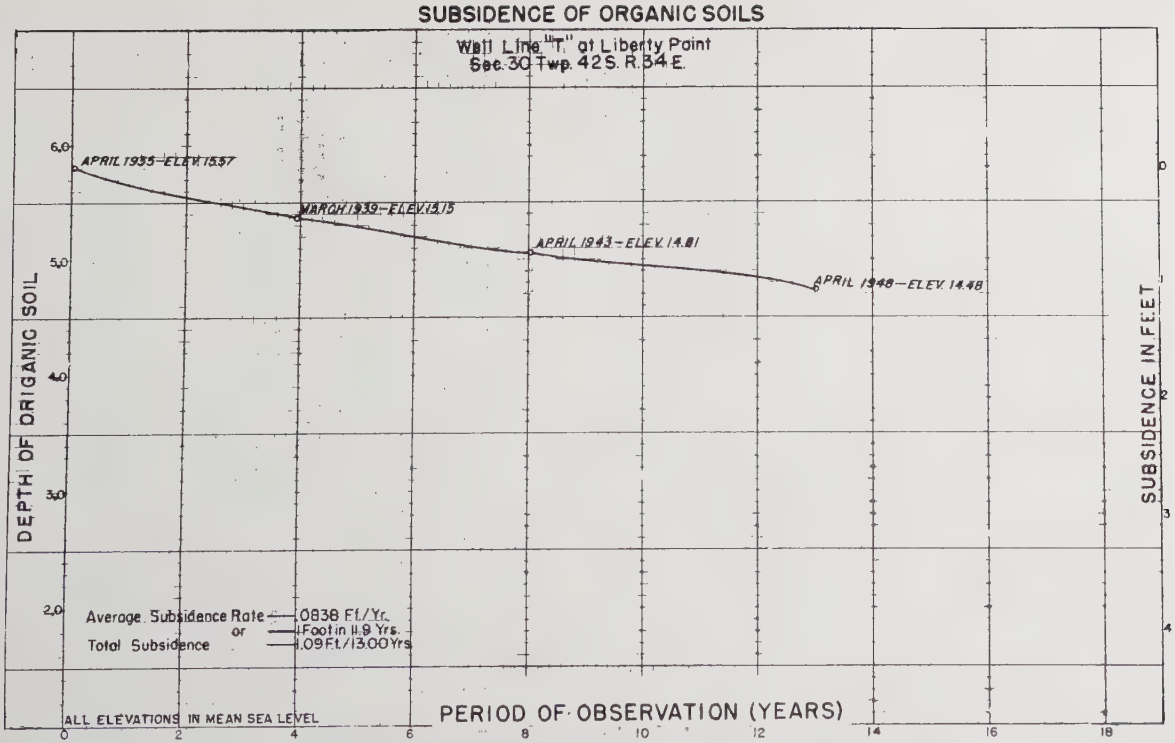

SUBSIDENCE OF ORGANIC SOILS
Well Line "T" at Liberty Point
Sec. 30 Twp. 42 S. R. 34 E.
APRIL 1935 - ELEV. 15.57
MARCH 1939 - ELEV. 15.15
APRIL 1943 - ELEV. 14.81
APRIL 1948 - ELEV. 14.48
DEPTH OF ORIGANIC SOIL
SUBSIDENCE IN FEET
Average Subsidence Rate — .0838 Ft./Yr.
or — 1 Foot in 11.9 Yrs.
Total Subsidence — 1.09 Ft./13.00 Yrs.
ALL ELEVATIONS IN MEAN SEA LEVEL
PERIOD OF OBSERVATION (YEARS)

Figure 10. This graph shows loss of surface elevation typical of Everglades peaty muck lands planted to sugarcane. The area was in cultivation prior to establishment of the profile line in 1935 and the average rate of soil loss has been about one foot in 12 years since that date.

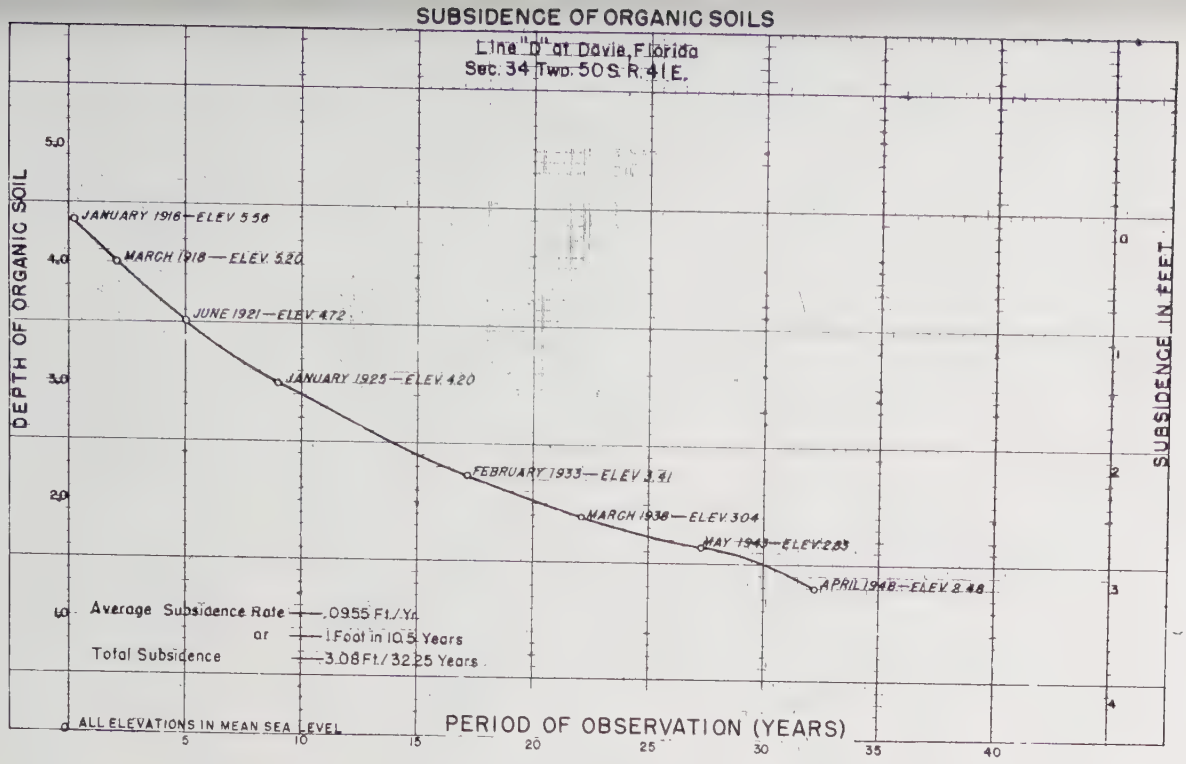

SUBSIDENCE OF ORGANIC SOILS
Line "D" at Davie, Florida
Sec. 34 Twp. 50 S. R. 41 E.
DEPTH OF ORGANIC SOIL
SUBSIDENCE IN FEET
JANUARY 1916—ELEV. 5.56
MARCH 1918—ELEV. 5.20
JUNE 1921—ELEV. 4.72
JANUARY 1925—ELEV. 4.20
FEBRUARY 1933—ELEV. 3.41
MARCH 1938—ELEV. 3.04
MAY 1943—ELEV. 2.83
APRIL 1948—ELEV. 2.48
Average Subsidence Rate —.0955 Ft./Yr.
or —1 Foot in 10.5 Years
Total Subsidence —3.08 Ft./32.25 Years
ALL ELEVATIONS IN MEAN SEA LEVEL
PERIOD OF OBSERVATION (YEARS)

Figure 11. This line was originally laid out on Everglades peat over sand. In some places along portions of the line, the peat has entirely disappeared with only the bare sand exposed.

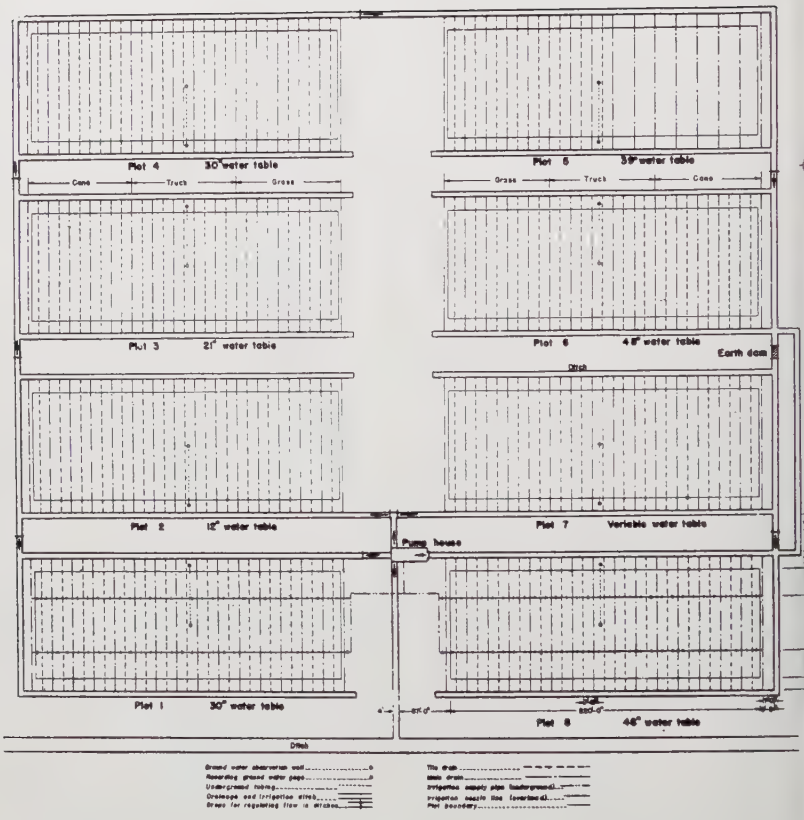


Figure 12. Showing the layout and arrangement of the field at the Everglades Experiment Station on which the experimental studies on controlled water table plots were conducted. One-third of each plot was planted to cane, to truck crops, and to grass as indicated. Water levels were held at various predetermined depths under each plot. Precise levels and soil analyses showed that loss of the peat soil depended almost directly upon the depth to the water table.

table on the subsidence of peat under controlled conditions and to study the effect of different water levels on the growth of various crops. During the first two years the water tables were held at levels varying approximately 9 inches between plots and about 6 inches between plots for the remaining years. Overhead spray was used on plots 1 and 8 to raise the water levels during the dry part of the year and the water in the variable plot, No. 7, was raised to within 6 inches of the surface and quickly lowered once each week except during wet periods. These studies were concluded in early 1943 at which time the surface elevations had declined from 6 to 14 inches for the various blocks below their 1935 level.

Table 1 tabulates the results of the studies showing the relationship of subsidence to the depth of the water table.

It will be noted that the portion of the plots planted to cane subsided less than those portions used for truck and grass crops. However, Clayton (12) has stated that this difference may be accounted for by the relative densities of the upper portion of the soil on the different plots and that it is doubtful if there is any appreciable difference in the rate of subsidence for the crops grown. Levels in the blocks where the water table was to be maintained deepest could not be held at these predetermined depths because of inability to keep the levels lower after the surface subsided as can be seen by inspecting the decrease in average depth of water table from year to year for plot number 6, Table 1.

The significant and most important results from these studies are summarized by the graph, Figure 13, showing the average annual subsidence per year as compared to the average depth of the water table as compiled from the results shown in the last column of Table 1. This figure illustrates very strikingly that, disregarding the top few inches of soil, the *rate of subsidence is dependent upon the depth of water table*. The higher the water table, the less the loss of soil and vice versa.

Inasmuch as change in density, as well as loss in surface elevation must be measured to determine true soil loss, samples were obtained annually to determine the loss in soil weight and the increase in ash content of the soil layer above the water table. Equipment was also installed which provided for the collection of soil gasses which were analyzed for CO_2 gas, the by-product of biochemical oxidation. The methods used and results obtained have been described in detail by Neller (10) who showed that the rate of oxidation as indicated by the production of CO_2 depended strikingly upon the height of the water table. Neller's work corroborated that the predominant factor in loss of soil mass in organic soils is the depth to water table. Thus, for soil conservation, water levels should be held as high as is compatible with crop production and field accessibility.

The controlled water table experiments show that good farming and better controlled farm water levels can result in increased production of crops at higher water levels than that now generally maintained on cropped areas, with consequent decrease in the present rate of soil losses. A brief outline of the results of these experiments as reported in the Annual Reports of the Florida Agricultural Experiment Station indicates for truck crops a water table of from 18 to 25 inches is optimum. Celery seems to do best at an 18 inch water level, while most other vegetables, such as beans and potatoes, grow better at a water level of about 24 inches. Pastures have produced well on water levels of 18 inches and even less when once established. Corn seems

SUBSIDENCE ON CONTROLLED WATER TABLE PLOTS
EVERGLADES EXPERIMENT STATION
1936 THROUGH 1942

* ** * ** * ** * ** * ** * ** *

PLOT NO.	DIVISION	CULTURE	1936		1937		1938		1939	
			DEPTH OF W.T.	SUBSI-DENCE	DEPTH OF W.T.	SUBSI-DENCE	DEPTH OF W.T.	SUBSI-DENCE	DEPTH OF W.T.	SUBSI-DENCE
1	East	Grass	2.24	0.14	1.93	0.13	1.88	0.11	1.82	0.09
	Center	Truck	2.29	.12	2.01	.10	1.96	.12	1.90	.11
	West	Cane	2.28	.15	2.05	.02	2.10	.04	2.07	.12
	Average		2.27	.14	2.00	.06	1.98	.10	1.93	.10
2	East	Grass	1.00	.08	0.94	.02	0.96	.01	0.99	.01
	Center	Truck	1.11	.04	1.04	.09	1.00	.06	1.01	.00
	West	Cane	1.13	.06	1.08	.01	1.13	.02	1.13	.09
	Average		1.08	.06	1.02	.04	1.03	.02	1.05	.03
3	East	Grass	1.58	.09	1.40	.04	1.44	.07	1.36	.06
	Center	Truck	1.69	.04	1.52	.07	1.55	.08	1.47	.03
	West	Cane	1.78	.07	1.63	.02	1.71	.02	1.63	.10
	Average		1.68	.07	1.52	.05	1.56	.05	1.49	.07
4	East	Grass	2.25	.12	1.90	.07	1.85	.10	1.88	.14
	Center	Truck	2.34	.12	2.00	.07	1.95	.09	1.94	.13
	West	Cane	2.42	.07	2.13	.02	2.12	.06	2.16	.06
	Average		2.34	.10	2.02	.05	1.98	.09	1.98	.11
5	East	Cane	2.54	.15	2.66	.03	2.73	.06	2.57	.09
	Center	Truck	2.50	.17	2.57	.12	2.55	.15	2.29	.19
	West	Grass	2.55	.20	2.60	.12	2.57	.15	2.35	.13
	Average		2.53	.18	2.61	.08	2.62	.12	2.40	.14
6	East	Cane	3.21	.19	3.04	.05	3.06	.12	2.88	.07
	Center	Truck	3.20	.22	2.96	.15	2.89	.21	2.61	.18
	West	Grass	3.23	.25	2.96	.18	2.90	.16	2.68	.12
	Average		3.21	.21	2.98	.13	2.95	.16	2.72	.13
7	East	Cane	3.11	.20	2.83	.04	2.86	.14	2.84	.07
	Center	Truck	3.11	.23	2.75	.18	2.71	.14	2.66	.14
	West	Grass	3.13	.26	2.78	.13	2.75	.15	2.69	.16
	Average		3.12	.23	2.79	.12	2.78	.14	2.74	.13
8	East	Cane	3.23	.23	2.88	.09	2.91	.17	2.76	.08
	Center	Truck	3.15	.21	2.78	.19	2.75	.19	2.57	.10
	West	Grass	3.09	.22	2.73	.14	2.75	.15	2.58	.13
	Average		3.15	.2.	2.80	.14	2.80	.18	2.63	.10
Intervening Months Between Measurements			13.5		12.75		11.5		13.0	

NOTE ALL MEASUREMENTS ARE IN FEET

SUBSIDENCE ON CONTROLLED WATER TABLE PLOTS
EVERGLADES EXPERIMENT STATION
1936 THROUGH 1942
(continued)

* ** * ** * ** * ** * ** * ** *

PLOT NO.	DIVISION	CULTURE	1940 DEPTH OF W.T.	1940 SUBSIDENCE	1941 DEPTH OF W.T.	1941 SUBSIDENCE	1942 DEPTH OF W.T.	1942 SUBSIDENCE	AVERAGE DEPTH OF W.T.	AVERAGE * ANNUAL SUBSIDENCE	AVERAGE * TOTAL SUBSIDENCE 1936-1942
1	East	Grass	1.77	0.14	1.77	0.14	1.59	.24	1.86	.1338	.99
	Center	Truck	1.78	.23	1.78	.06	1.65	.23	1.91	.1311	.97
	West	Cane	2.00	.13	2.02	.12	1.85	.24	2.05	.1054	.78
	Average		1.86	.17	1.86	.11	1.69	.23	1.94	.1230	.91
2	East	Grass	0.98	.10	0.91	.11	1.23	.13	1.00	.0622	.46
	Center	Truck	1.00	.10	.95	.05	1.31	.13	1.06	.0635	.47
	West	Cane	1.13	.01	1.12	.05	1.47	.16	1.17	.0486	.36
	Average		1.03	.07	1.00	.07	1.34	.14	1.08	.0581	.43
3	East	Grass	1.40	.16	1.37	.12	1.34	.16	1.41	.0946	.70
	Center	Truck	1.52	.17	1.48	.14	1.45	.14	1.52	.0905	.67
	West	Cane	1.68	.09	1.72	.07	1.69	.20	1.69	.0770	.57
	Average		1.54	.13	1.52	.12	1.49	.16	1.54	.0878	.65
4	East	Grass	1.90	.16	1.83	.23	1.66	.20	1.89	.1365	1.01
	Center	Truck	1.97	.23	1.89	.16	1.76	.20	1.98	.1361	1.00
	West	Cane	2.29	.11	2.24	.21	2.10	.19	2.21	.0973	.72
	Average		2.05	.16	1.99	.20	1.84	.20	2.03	.1230	.91
5	East	Cane	2.58	.09	2.56	.12	2.37	.31	2.57	.1149	.85
	Center	Truck	2.21	.18	2.11	.18	1.93	.23	2.31	.1649	1.22
	West	Grass	2.29	.20	2.17	.20	1.97	.27	2.36	.1716	1.27
	Average		2.36	.15	2.28	.17	2.09	.27	2.41	.1500	1.11
6	East	Cane	2.71	.11	2.67	.15	2.35	.28	2.85	.1311	.97
	Center	Truck	2.33	.21	2.23	.16	1.93	.24	2.59	.1851	1.37
	West	Grass	2.44	.18	2.35	.19	2.02	.27	2.65	.1824	1.35
	Average		2.49	.16	2.41	.17	2.10	.27	2.69	.1662	1.23
7	East	Cane	2.76	.08	2.73	.10	2.58	.32	2.82	.1284	.95
	Center	Truck	2.49	.17	2.38	.18	2.27	.17	2.62	.1635	1.21
	West	Grass	2.53	.14	2.41	.23	2.23	.25	2.65	.1784	1.32
	Average		2.59	.13	2.50	.17	2.36	.25	2.70	.1581	1.17
8	East	Cane	2.63	.12	2.50	.16	2.36	.24	2.75	.1473	1.09
	Center	Truck	2.43	.15	2.28	.14	2.16	.23	2.59	.1635	1.21
	West	Grass	2.39	.19	2.22	.16	2.07	.26	2.55	.1689	1.25
	Average		2.47	.15	2.34	.15	2.20	.24	2.63	.1581	1.17
Intervening Months Between Measurements			12.5		12.25		14.5		TOTAL MONTHS — 89.		

NOTE: ALL MEASUREMENTS ARE IN FEET

* CALCULATED FROM 1936 ELEV. MINUS 1942 ELEV.

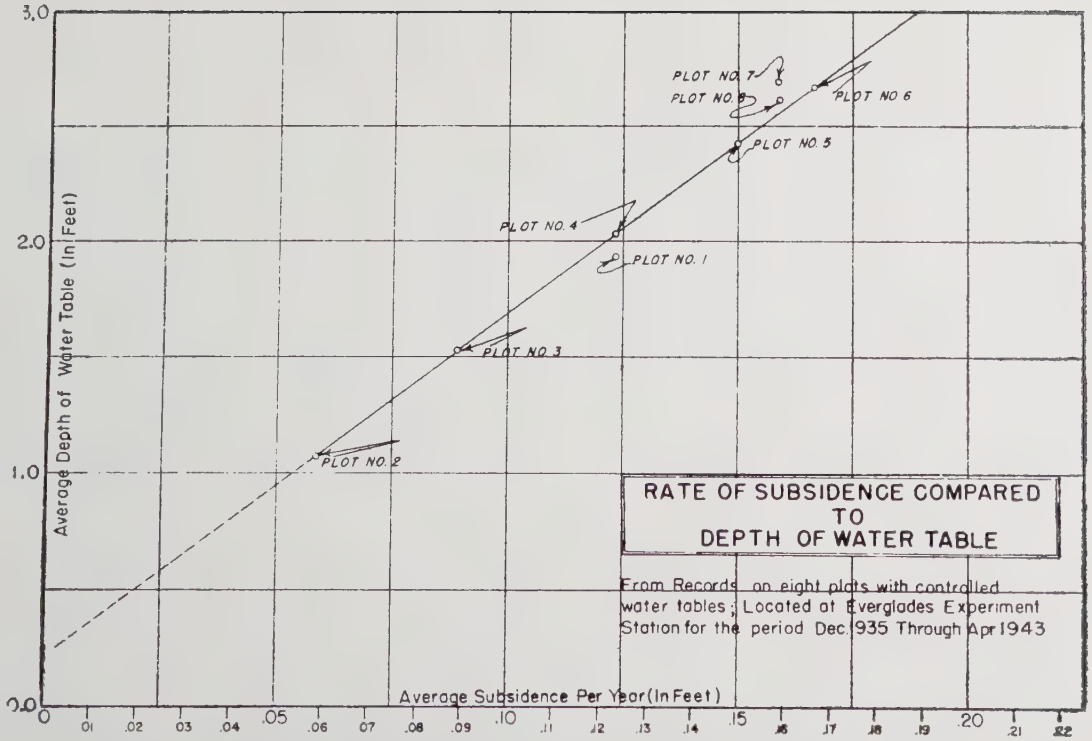


Figure 13. This shows very strikingly that the rate of subsidence for organic soils is dependent upon the depth to the water table. The higher the water table, the lower the soil loss and vice versa. Obviously, the water table should be held as high as crop and field requirements will permit to prolong the life of these lands

to do best on a lower water level of 24 to 30 inches. The tolerance of sugarcane to high water levels was found to vary considerably with the variety, some producing better at high levels and others at low. This is no doubt true to some extent with other crop varities as well.

From the graph, Figure 13, showing annual rate of subsidence and the preceding crop level requirements, the rate of soil loss under controlled farm levels is given below.

Culture	Best Water Level	Annual Loss in Inches	Years Required to lose 1 foot of peat
Pasture Grasses	(14 to 18)"	3/4 to 1	12 to 16 yrs.
Truck	(18 to 24)"	1 to 1-1/2	8 to 12 yrs.
Corn	(24 to 30)"	1-1/2 to 1-7/8	7 to 8 yrs.

On lands where seasonal crops are grown, it is feasible to practice flood fallow whereby the land is covered by water during the period of no cultivation. This practice has been used in the past primarily for pest control. Obviously its wide spread use would add many years to the life of the peat soils.

From the results of the controlled water table experiments, it is believed that the rate of soil loss to be expected over the whole of the cultivated area will average *1 foot in 10 years* after the initial subsidence through compaction has occurred.

AREA SUBSIDENCE STUDIES - 1912 TO 1950

Past history of subsidence in the deeper organic soils of the upper Everglades is a sad picture of misunderstanding of the problem and abuse of the soil through bad drainage practices. The failure to reclaim and develop the Everglades in progressive units has resulted in great soil losses that could have been largely prevented.

The early concept for the reclamation of the Everglades was the extension of the several short coastal rivers through the Everglades to Lake Okeechobee. Such a plan proposed to reclaim the whole of the Everglades as well as to control Lake Okeechobee. It was soon found that the control of Lake Okeechobee could not be accomplished by the Everglades canal system and other control channels were constructed leaving the original canal system to serve the Everglades lands. The inadequacy of this system to prevent flooding and agricultural loss in the Everglades is well known. The effectiveness of the canal system in overdraining the organic soils of the Everglades, especially the soils not used for agricultural purposes, is not so well known.

The most striking presentation of the effects of this overdrainage is best shown by a comparison of the original depths of organic soil with intervening periods and with the present depths. While data is not complete for the reconstruction of the soil depths by short periods, information was available for reconstruction by longer periods. These will be discussed chronologically hereafter.

The area reconstructed was the total area of organic soils within the Ever-

glades Agricultural Area as previously described. This is an area of 987 square miles of the larger 1018 square miles proposed to be protected by levees and drained by primary pumping plants. Maps hereafter referred to, showing the organic soil depths at various periods of time, indicate this smaller area.

Original Soil Depths - 1912.

It is assumed that before the construction of the Everglades canal system by the Everglades Drainage District, the organic soils were at their maximum depth. Data is available from the early canal surveys to reconstruct these original and maximum organic soil depths with reasonable accuracy. These depths of organic soil to underlying rock or mineral soils are shown on Figure 14.

It will be noted that the organic soil depths ranged from 5 feet near Miami Canal at Palm Beach - Broward County Line - to 17 feet near Lake Okeechobee north of West Palm Beach Canal. Depths of soil decreased generally from north to south, feathering out along the mineral soil borders of the Everglades. Generally, the deeper organic soils of the Everglades fill the old floodway channels along the east and west margins.

Intermediate Period After Drainage - 1925.

By this time, more data are available from which to reconstruct the soil depths in the area. Everglades Drainage District had compiled a topographic map showing the contours of the area based on the data obtained from the surveys connected with the construction and proposed expansion program of the canal system. The Department of Agriculture was well along with the studies on subsidence lines, adding valuable spot information on soil elevations and depths. The organic soil depths at this period are shown on Figure 15.

The major change since the beginning of drainage was a general subsidence of the whole area. The definite subsidence valleys along the arterial canals were not as well defined as in later years in most instances.

Intermediate Period After Drainage - 1940.

The surveys of the Soil Conservation Service, previously described, resulted in the most complete topographic map to this date. These surveys also provided a contour map of the underlying rock and mineral soils. These elevations were the basis for the reconstruction of the soil depths as applied to earlier surface elevation data. Soil depths in 1940 are shown in Figure 16.

The subsidence valleys so evident along the drainage canals were more pronounced during this period than they probably will be again. The area as a whole continued to subside but the effects of overdrainage was being emphasized along the canals. More of the area was being cultivated, making greater demands upon drainage that resulted in excessively low canal regulation.

The Present Period - 1950.

Surveys by the Corps of Engineers in connection with investigations for the works of the current flood control plan supplied the information for the determination of soil depths at this period. They also confirmed the underlying rock and mineral soils elevations reflected by earlier surveys. Figure 17 shows the present depth of organic soil.

It is notable that the general loss for the past ten years has been approximately one foot. Drainage regulation during this period was not as favorable to

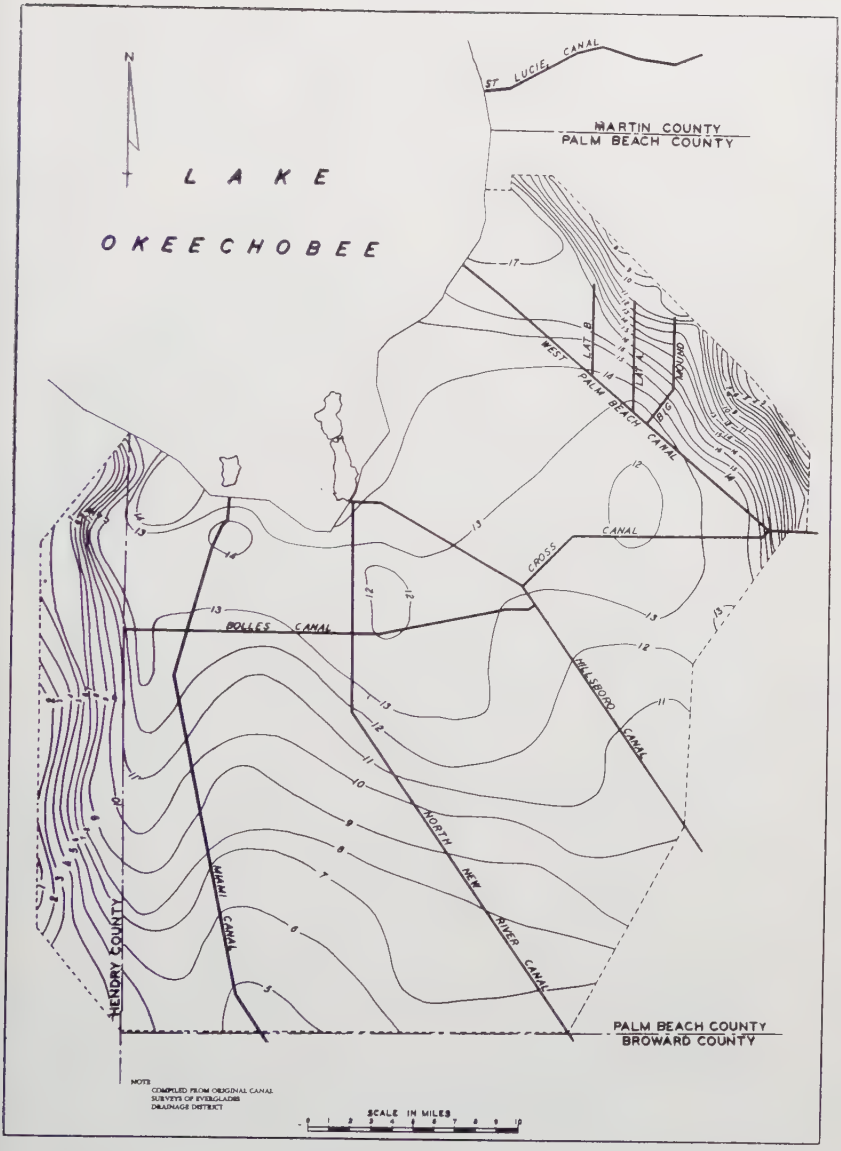


Figure 14. Map of the Everglades Agricultural Area showing the depth of the peat and muck soils in the year 1912 prior to drainage. Depth of underlying material is shown in feet.

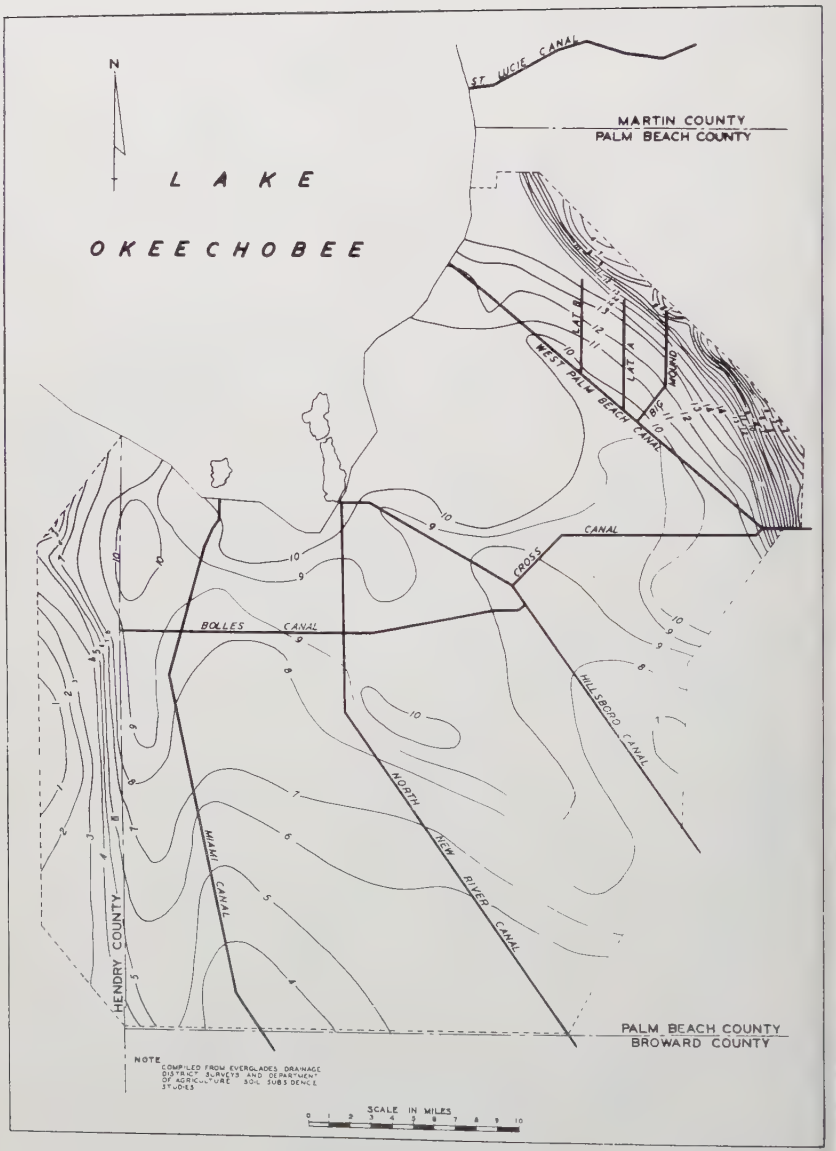


Figure 15. Soil depths for the year 1925, the intermediate period after drainage is shown.

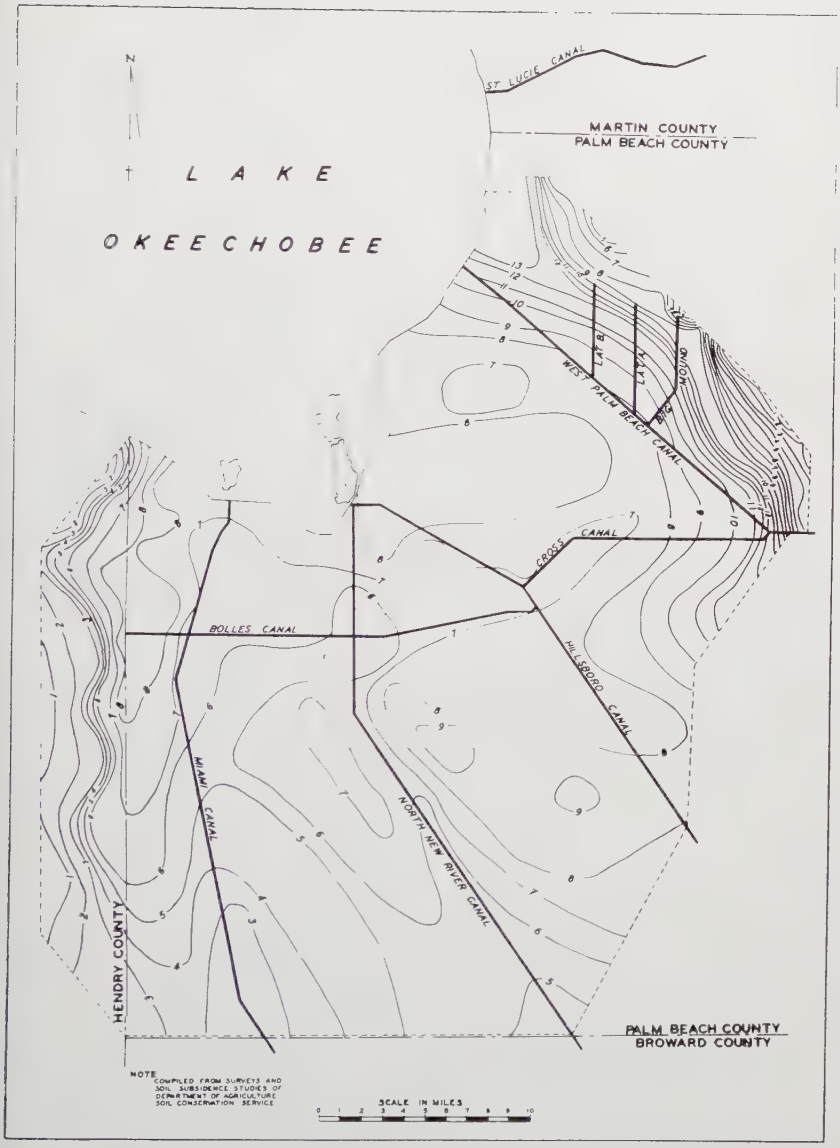


Figure 16. Soil depths in the area as shown by the surveys of the Soil Conservation Service in 1940.

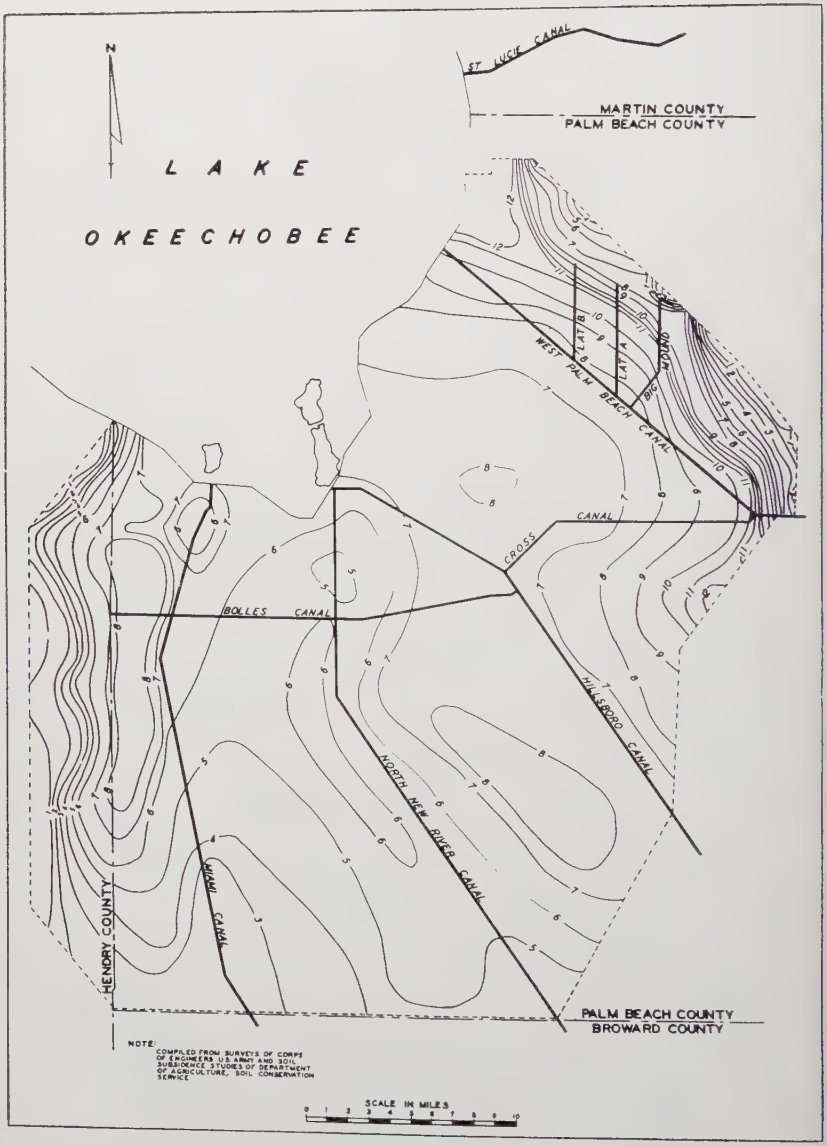


Figure 17. The present period - 1950. This map prepared from recent surveys shows a total loss in soil volume within the studied area of 40 percent since drainage in 1912.

the conservation of the soil as desirable, but, particularly during the latter half of the period, a conscientious effort was made to hold water levels as high as practicable in the arterial canals during the dry seasons within the limits possible using existing control structures. Many farmers and ranchers were becoming conscious of the relationship of water tables to soil losses and, with improved local drainage facilities were losing their fear of flooding under normal conditions that in past years had influenced the practice of overdrainage as a crop protective measure.

The subsidence valleys along the arterial canals are not quite as pronounced as in 1940, probably due to generally higher regulation of the arterial canals in the dry seasons during this period. However, soil losses in the higher undeveloped lands between the canals continued at about the expected rate. The ominous part of the present picture is the evident creeping northward, from the southern boundary of the area, of the spreading range of shallower soils that do not justify development for long term use.

Summary of Area Subsidence from the Original Condition to the Present

Forty years of almost uncontrolled drainage and development has taken its toll of the organic soils of the Everglades Agricultural Area. Of the original depth, approximately three feet has been lost in the vicinity of Miami Canal; seven feet has been lost from the area near Bolles and North New River Canals; and five feet from the deep peat area north of West Palm Beach Canal near Lake Okeechobee. The total volume in the studied area has decreased by 40%.

The losses in the undeveloped lands have occurred to almost the same degree as in the lands in cultivation. Fires have been a contributing hazard in the wild lands where they were very difficult to successfully combat. It is apparent that a continued loss from both cropped and undeveloped lands is inevitable under present and foreseeable land use and water control practices. As heretofore stated, the average probable rate of loss will be approximately one foot in ten years.

The certainty of continuing soil losses in the organic soils of the Everglades must be squarely faced. In order that the facts pertaining to the future of the area be available for the general information of the public, it is believed desirable to project the subsidence picture into the future. This will be presented hereafter, based on the known factors influencing subsidence, assuming certain conditions of land development and use.

PREDICTED SUBSIDENCE - 1950 to 2000

Based on the known factors of subsidence, the future of the organic soils, as to their years of usefulness, can be estimated with reasonable accuracy. The subsidence picture will be extended by ten year periods to the year 2000 A.D., beyond which period the value of such extension will be apparent.

The Near Future Period - 1960.

It has been assumed that by 1960 the entire Everglades Agricultural Area will be under dike and pump and developed for agricultural purposes. By using this assumption, the lands now in use and under pump should continue to subside at the average rate of one foot in ten years. However, the present area of wild lands, assumed to be placed in cultivation by 1960, will take an initial subsidence of approximately six inches soon after being placed in cultivation

in addition to the normal rate, or a total of about eighteen inches for the 10 year period. This initial loss, inevitable in converting wild land to agricultural use, was taken over the entire area prior to 1960 to simplify long range projection of the subsidence losses. Regardless of when this initial loss is taken, the end result is the same.

By the end of this period the area of lands having only short term agricultural use is noticeably spreading northward into the heart of the area. The margins of peat soils lying over mineral soils is shrinking toward the center of the organic soils area. The area, as a whole, by 1960, however, is still largely capable of sustaining long term agriculture and the growing of crops requiring mole drainage practices. The soil depths at this period are depicted on Figure 18.

The situation mentioned above, of the shrinking of the organic soils from the mineral soil margins of the Everglades, is not a serious factor. Where these mineral soils have depth, their continued use and productiveness is almost unlimited. It is where the organic soils are immediately underlain by rock that subsidence is the determining factor of the length of the land's productiveness.

As the organic soils over rock become shallower, there will be the necessity of deepening the farm drainage ditches into the rock. This is believed to be entirely within the economics of the land's productiveness. However, when the organic soil has subsided to a point where it does not have sufficient depth to permit mole draining, it can only be used for more water tolerant crops. The soil use under these conditions may still be economically feasible. When the soil depth has subsided to only one foot above rock, it is questioned that this depth of soil over dense rock can be maintained below the saturation point sufficiently to be used economically. Further, a real difficulty will arise when the necessary water table for a particular crop falls below the surface of the rock when the supply will be lost by capillarity to the peat.

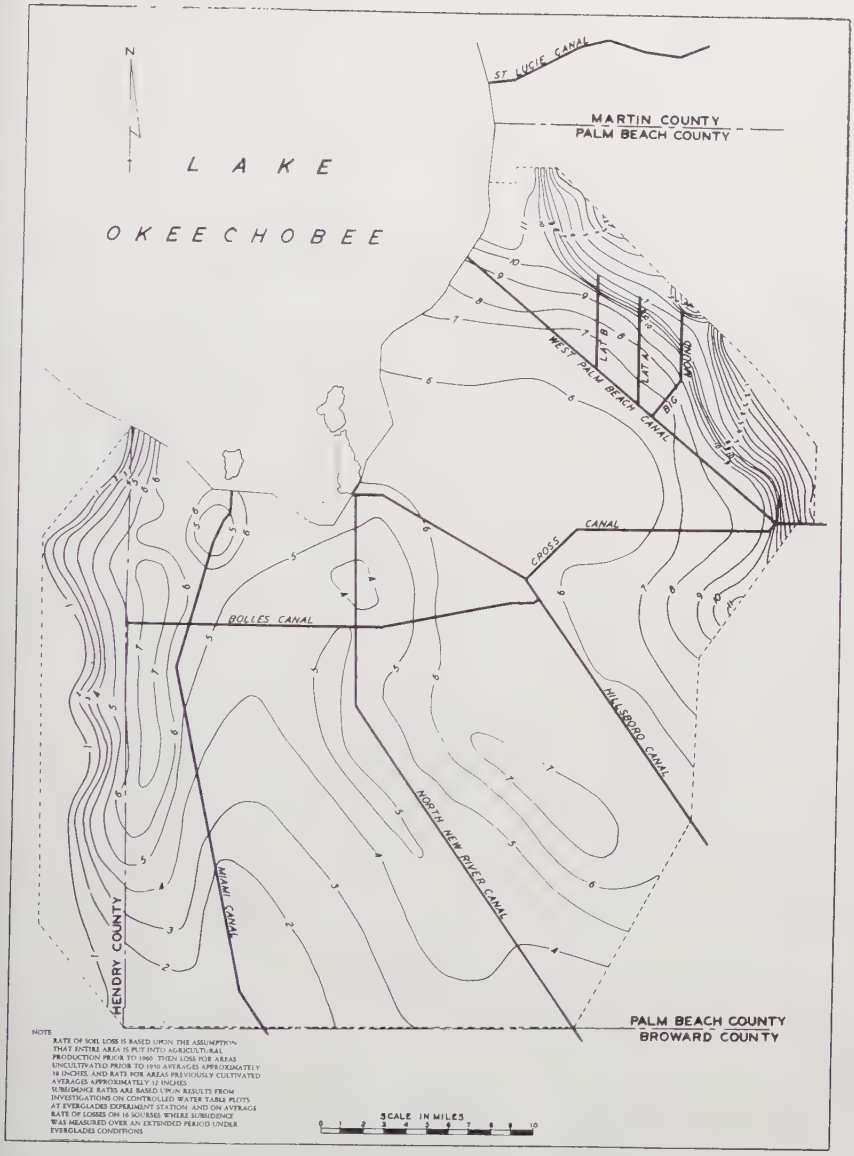
Successive Future Intermediate Periods - 1970, 1980 and 1990

These periods have been treated as a group because there is no particular reason to differentiate between them. The area continues to subside as a whole and the margins over mineral soil to shrink inward. These several periods are shown on Figures 19, 20 and 21.

By 1990, much of the area will probably be too shallow in soil depth to support an economical agriculture. A larger part will be of such shallow depth that mole drainage will be impracticable and agricultural use will be limited to pastures and water tolerant crops. The organic soils suitable for so-called long range development will be restricted to a small area north of the West Palm Beach Canal and a small acreage along the narrow rim of higher mineral soils that border Lake Okeechobee.

The Period - 2000

By this time most of the Everglades Agricultural Area will have subsided to a degree where it is doubtful that economical agriculture can be supported generally. Some agricultural use on a normal scale will still be possible on small areas north of the West Palm Beach, south of the Cross Canal and near the rim of Lake Okeechobee. The detailed contours showing this small area bordering Lake Okeechobee does not appear on any of the plates of the Everglades Agricultural Area as it is too small to be shown at the scale of the plates.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NOTE
RATE OF SOIL LOSS IS BASED UPON THE ASSUMPTION THAT ENTIRE AREA IS PUT INTO AGRICULTURAL PRODUCTION PRIOR TO 1960. THEN LOSS FOR AREAS UNCULTIVATED PRIOR TO 1910 AVERAGES APPROXIMATELY 19 INCHES, AND RATE FOR AREAS PREVIOUSLY CULTIVATED AVERAGES APPROXIMATELY 12 INCHES.
SUBSIDENCE RATES ARE BASED UPON RESULTS FROM INVESTIGATIONS ON CONTROLLED WATER TABLE PLOTS AT EVERGLADES EXPERIMENT STATION AND ON AVERAGE RATE OF LOSSES ON 16 SOURSES WHERE SUBSIDENCE WAS MEASURED OVER AN EXTENDED PERIOD UNDER EVERGLADES CONDITIONS
SCALE IN MILES
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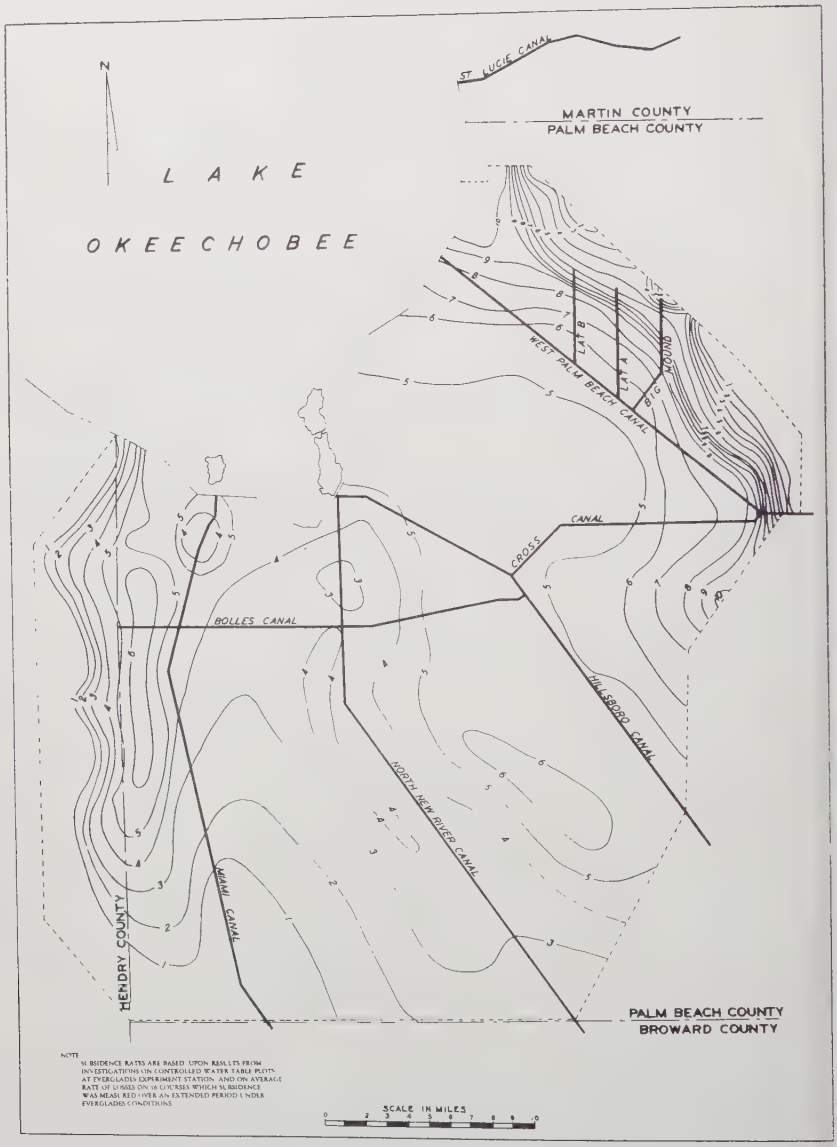
Figure 18. Predicted soil depths for 1960. The following group of maps show the probable depths of organic soil which will remain as subsidence continues in accord with the rates outlined in the text.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SUBSIDENCE RATES ARE BASED UPON RESULTS FROM INVESTIGATIONS ON CONTROLLED WATER TABLE PLOTS AT EVERGLADES EXPERIMENT STATION AND ON AVERAGE RATE OF LOSSES ON 16 COURSES WHICH SUBSIDENCE WAS MEASURED OVER AN EXTENDED PERIOD UNDER EVERGLADES CONDITIONS
SCALE IN MILES
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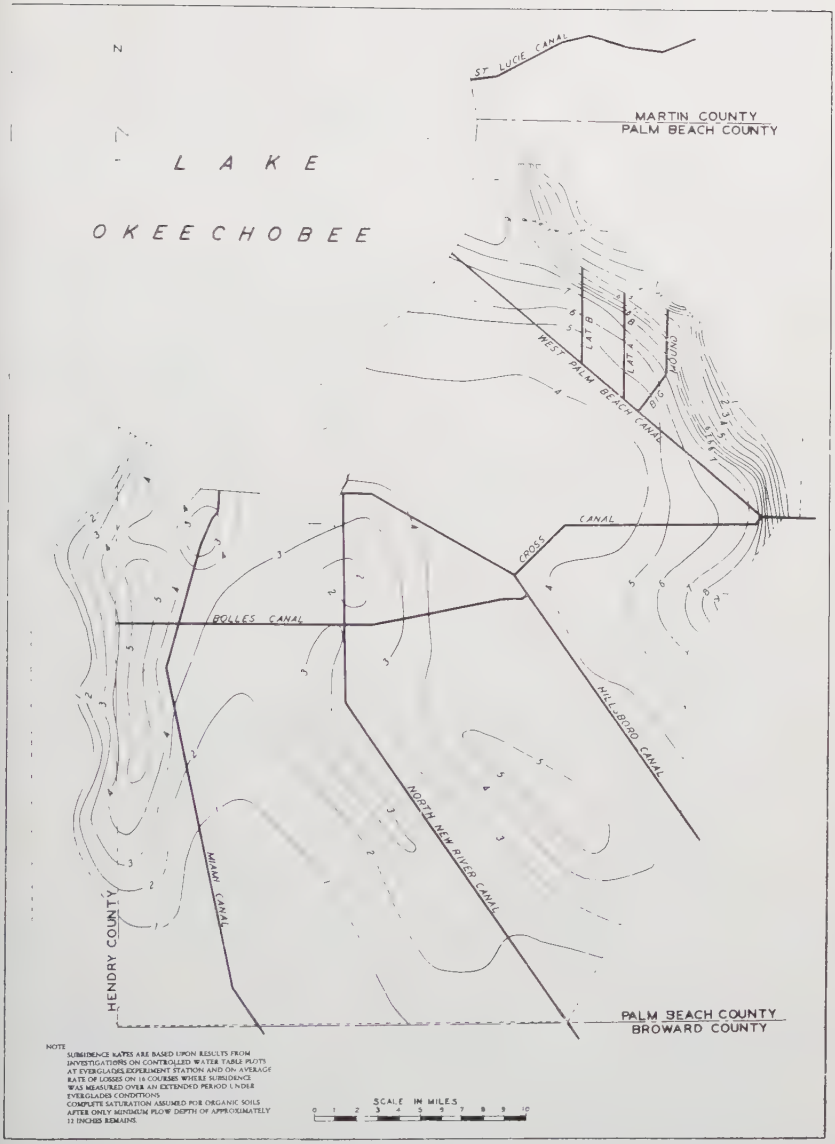
Figure 19. Predicted soil depths for 1970. The soils will continue to subside so that a large part of the area will be unsatisfactory for mole drainage which requires peat soils in excess of 3 ft. depth.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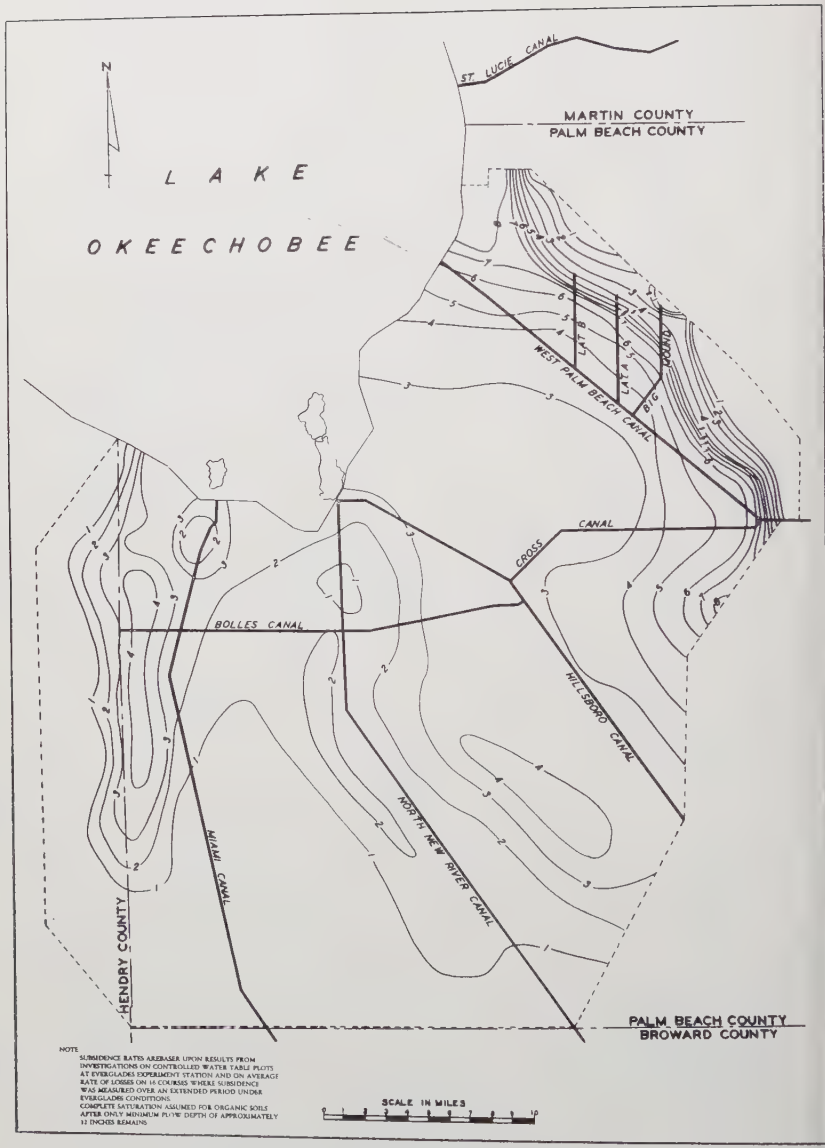
NOTE
SUBSIDENCE RATES ARE BASED UPON RESULTS FROM INVESTIGATIONS ON CONTROLLED WATER TABLE PLOTS AT EVERGLADES EXPERIMENT STATION AND ON AVERAGE RATE OF LOSSES ON 16 COURSES WHERE SUBSIDENCE WAS MEASURED OVER AN EXTENDED PERIOD UNDER EVERGLADES CONDITIONS
COMPLETE SATURATION ASSUMED FOR ORGANIC SOILS AFTER ONLY MINIMUM PLOW DEPTH OF APPROXIMATELY 12 INCHES REMAINS.
SCALE IN MILES
0 1 2 3 4 5 6 7 8 9 10

Figure 20. Predicted soil depths for 1980. The soils will continue to lose depth as a whole and the margins over mineral soils will shrink inward noticeably. A good portion of the area adjacent to the lower Miami Canal will probably already be below plow depth.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COMPLETE SATURATION ASSUMED FOR ORGANIC SOILS AFTER ONLY MINIMUM PEAT DEPTH OF APPROXIMATELY 12 INCHES REMAINS
SCALE IN MILES
0 1 2 3 4 5 6 7 8 9 10

Figure 21. Predicted soil depth - 1990. A considerable part of the area will be so shallow in depth that agricultural use will be limited to pasture and water tolerant crops, and a large part will be too shallow to support an economical agriculture.

Figure 22 shows the estimated soil depths of the Everglades Agricultural Area in the year 2000. It is evident that by this time a large part of the area will have been abandoned. This abandonment of large areas may increase the problems on lands still struggling to produce crops and may hasten the abandonment of practically all of the central part of the area. It is almost certain by this time that it will not be economically feasible to have water control of the whole of the area, which is also a factor contributing to final abandonment.

Summary of Area Subsidence from the Present Date to 2000 A.D.

It is unquestionable that, in the light of expected subsidence and probable land use practices, the agricultural life of the organic soils in the Everglades Agricultural Area will be almost ended by the year 2000. An aroused consciousness of the seriousness of the problem and better maintenance of water table practices may somewhat add to the soil life locally, but in general, large scale abandonment by approximately the year 2000 is the logical result that can be expected.

SUMMARY DISCUSSION OF SUBSIDENCE

Observations and analyses of area subsidence, subsidence lines and controlled subsidence plots definitely prove the certainty of soil loss associated with agricultural use of organic soils or non-use of those soils, if drained, and the relationship of the ground water table to that loss. Accepting these losses, it is timely to review the effects and plan future land use practices.

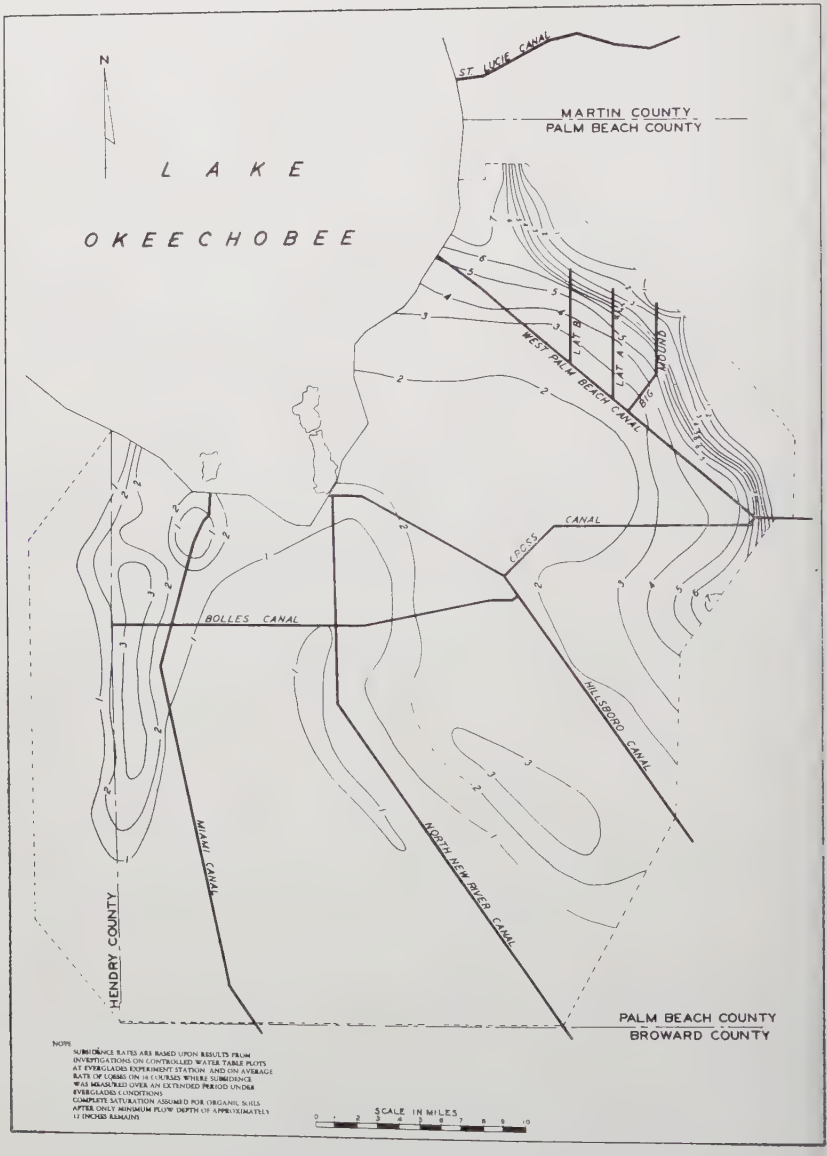
Figure 23 shows the location of typical cross-sections of the area which are shown on Figures 23 and 24. Study of Figures 23 and 24, indicates that as a whole the peat soils have subsided at a more or less uniform rate. This same pattern of subsidence may be expected in the future. Analyzed for periods of thirty years, as shown on the figures referred to above, the approximate total loss in cross-sectional area from the original for each period is as follows:

1912	None
1940	32%
1970	66%
2000	88%

With continued subsidence, the remaining soil will be of a somewhat greater density than the original. However, as most peats of the Everglades are of low mineral content, this increase of the soil density will have little effect on the total subsidence, at least to the point where agriculture is impracticable.

With continued loss in surface elevations the problems of water control increase. When organic soils shrink to less than three feet of depth, mole draining becomes impracticable. Thereafter, land use will be restricted to crops having a greater tolerance to water. The loss of soil elevation creates problems of drainage. Surplus water from farms must generally be discharged against increasingly higher stages of the main drainage canals that are presently more or less fixed in their regulation. This same condition tends to increase seepage that must be combatted by the farmer in providing water control for his lands.

The depth of organic soil controls the economic use that can be made of the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BOLLES CANAL
HILLSBORO CANAL
NORTH NEW RIVER CANAL
MIAMI CANAL
HENDRY COUNTY
PALM BEACH COUNTY
BROWARD COUNTY
NOTE
SUBSIDENCE RATES ARE BASED UPON RESULTS FROM INVESTIGATIONS ON CONTROLLED WATER TABLE PLOTS AT EVERGLADES EXPERIMENT STATION AND ON AVERAGE RATE OF LOSS ON 14 COURSES WHERE SUBSIDENCE WAS MEASURED OVER AN EXTENDED PERIOD UNDER EVERGLADES CONDITIONS.
COMPLETE SATURATION ASSUMED FOR ORGANIC SOILS AFTER ONLY MINIMUM PLOW DEPTH OF APPROXIMATELY 12 INCHES REMAINS
SCALE IN MILES
0 1 2 3 4 5 6 7 8 9 10

Figure 22. Predicted subsidence - 2000 A.D. By this time most of the Everglades Agricultural Area will have subsided to the point where there will probably be wide scale abandonment over much of the area. Water control problems on the remainder of the area will be intensified.

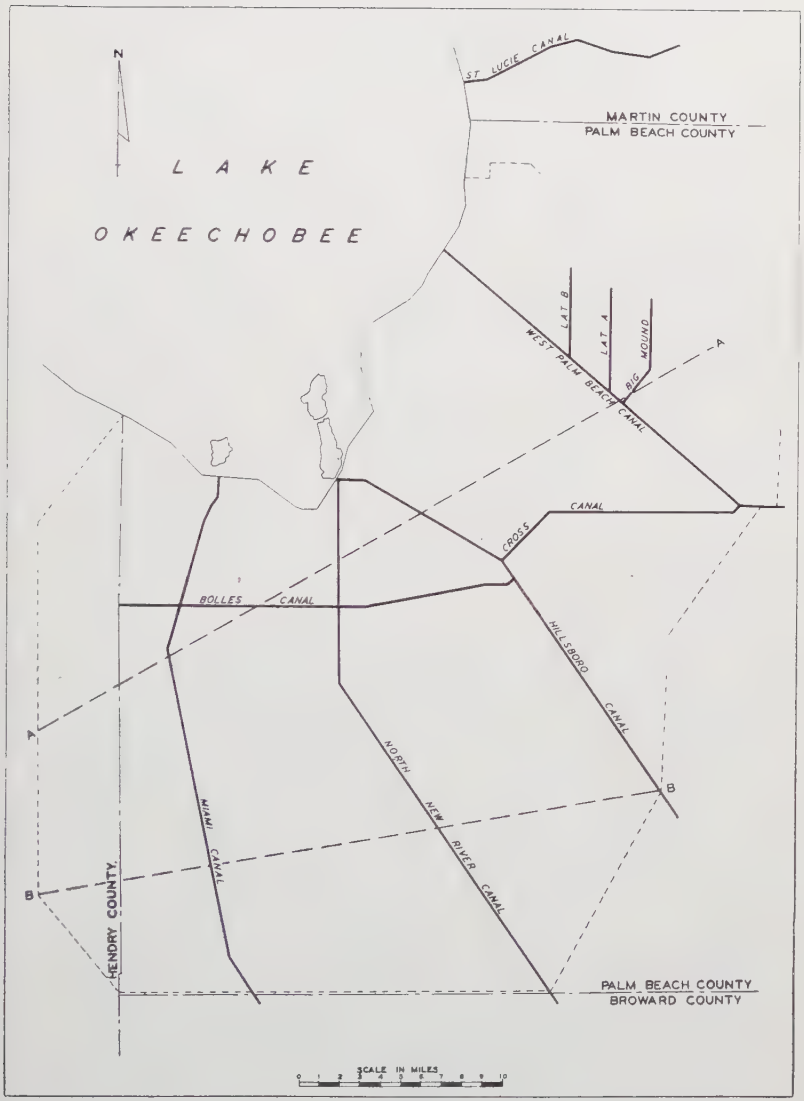

Figure 23. Map of the Everglades Agricultural Area showing the location of cross-section "A-A" as shown in Figure 24, and of cross-section "B-B" as shown in Figure 25.

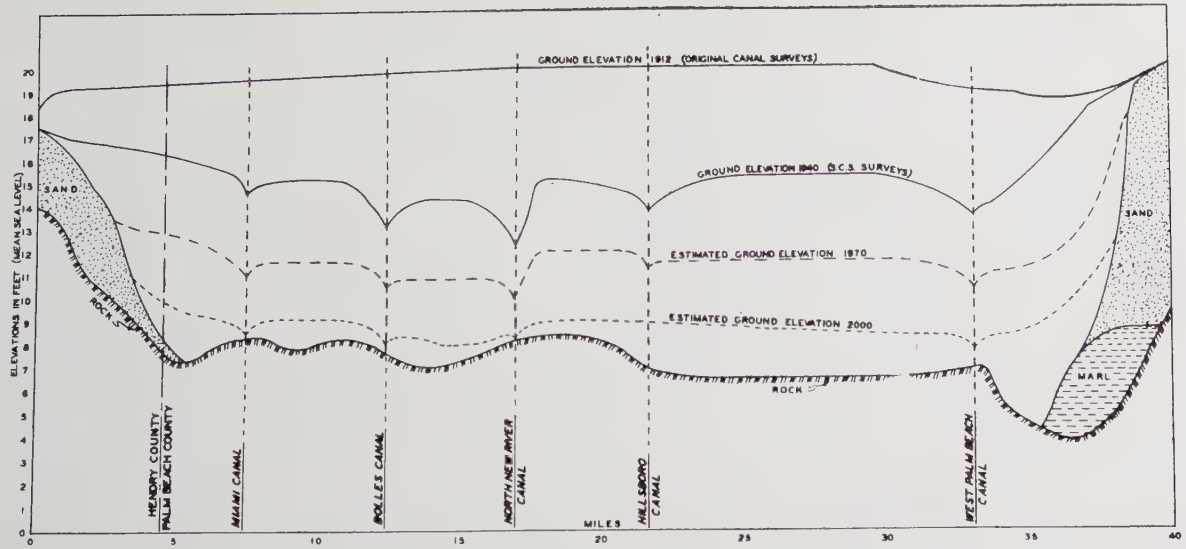

Figure 24. Cross-sectional view through the upper Everglades along line "A-A" showing original surface elevations, and the elevation in 1940 as shown by topographic surveys. Estimated ground elevations for the year 1970 and for 2000 A.D. are also shown.

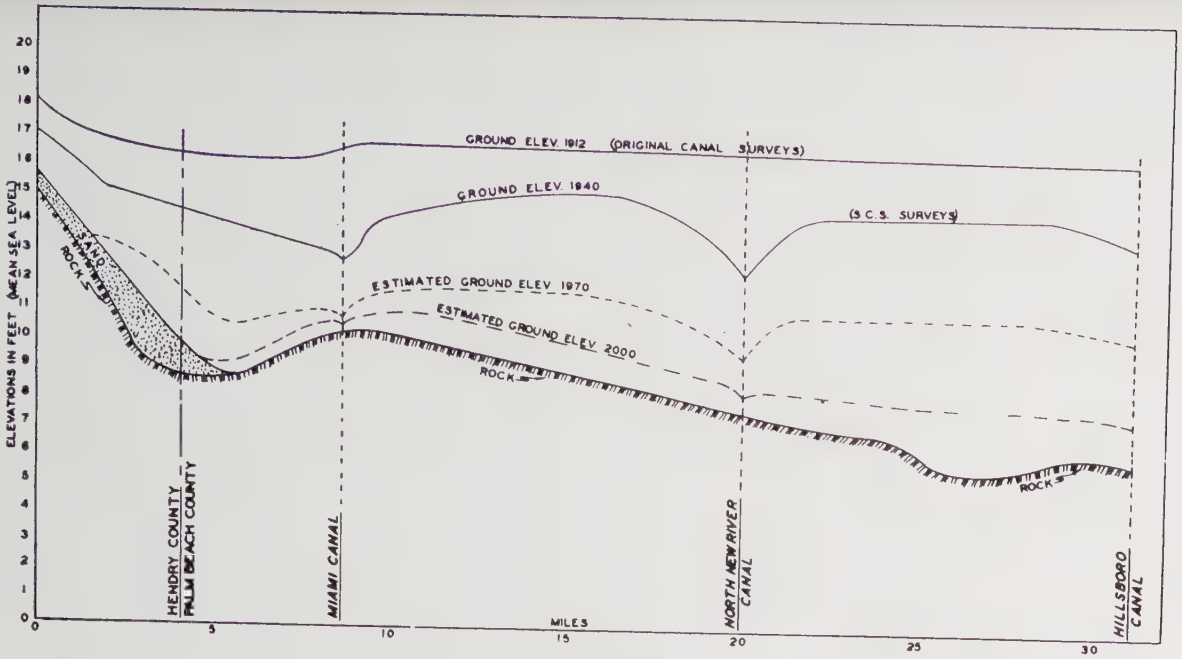

Figure 25. Cross-sectional view through the lower part of the Everglades Agricultural Area along line "B-B". From sections "A-A" and "B-B" it was found that the total loss in sectional area from the original was approximately 32 percent to 1940. It is estimated that the total loss will be 66 percent by 1970, and 88 percent by 2000 A.D.

land. It is questionable if extensive development for long time use is justified in land where the virgin soil is less than 5 feet in depth. The economic justification for development of raw lands of less than 3 feet in depth where initial subsidence must be taken, to the extent of even limited excavation of ditches into rock, is doubtful. The value of future markets for Everglades farm products and future cost of development may well be the controlling factor in the use and extent of use of Everglades lands in the later periods.

As mentioned heretofore, it is considered impracticable to mole drain organic soils of less than 3 feet depth. Everglades peat soils of a deeper depth are readily adaptable to mole draining operations and practices within limits, and the cost is nominal. The justification of providing tile drainage in soils too shallow to mole drain has not been determined, but is not believed to be economically feasible except perhaps for special crops. It is not believed that soil less than 1 foot depth can be used economically for agricultural purposes.

Classifying the soils of the Everglades Agricultural Area according to land use and development justification, by periods represented by Figures 14 to 22 inclusive, the following table has been prepared:

PERCENTAGE OF TOTAL ORGANIC SOILS

Year	*Depth in ft.* 0.0 to 1.0	1.0 to 3.0	3.0 to 5.0	Over 5.0
1912	0.1	1.2	3.4	95.3
1925	0.6	3.1	7.8	88.5
1940	0.8	6.8	7.2	85.2
1950	1.7	6.7	13.6	78.0
1960	4.4	12.4	28.1	55.1
1970	10.7	16.2	27.8	45.3
1980	16.6	28.4	41.3	13.7
1990	27.0	28.2	37.8	7.0
2000	45.3	42.2	8.8	3.7

To obtain the maximum benefits from the organic soils of the Everglades Agricultural Area, the following objectives should be considered in all future planning for water control and land use:

1. That land development be predicated on the expected life of the soils and the land capability.
2. That land and water use practices be improved, where possible, to obtain the maximum productive life of the soils.
3. That the design of water control systems be such that will provide the maximum opportunity to achieve the best land use practices.
4. That all efforts be made to provide adequate water control facilities and place the organic soils in use as quickly as possible in order to forestall the wasteful loss of soils in lands not now in use.

5. That research be intensified and that the public be kept informed on the progress made on the more beneficial land use and water control practices as developed in order that everything possible may be done to conserve and prolong the remaining life of these soils.

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4. Clayton, B.S. Nature and extent of surface subsidence of the organic soils of the Everglades. *Part I, Soil Sci. Soc. of Fla., Vol. V-A, Proc. 1943.*

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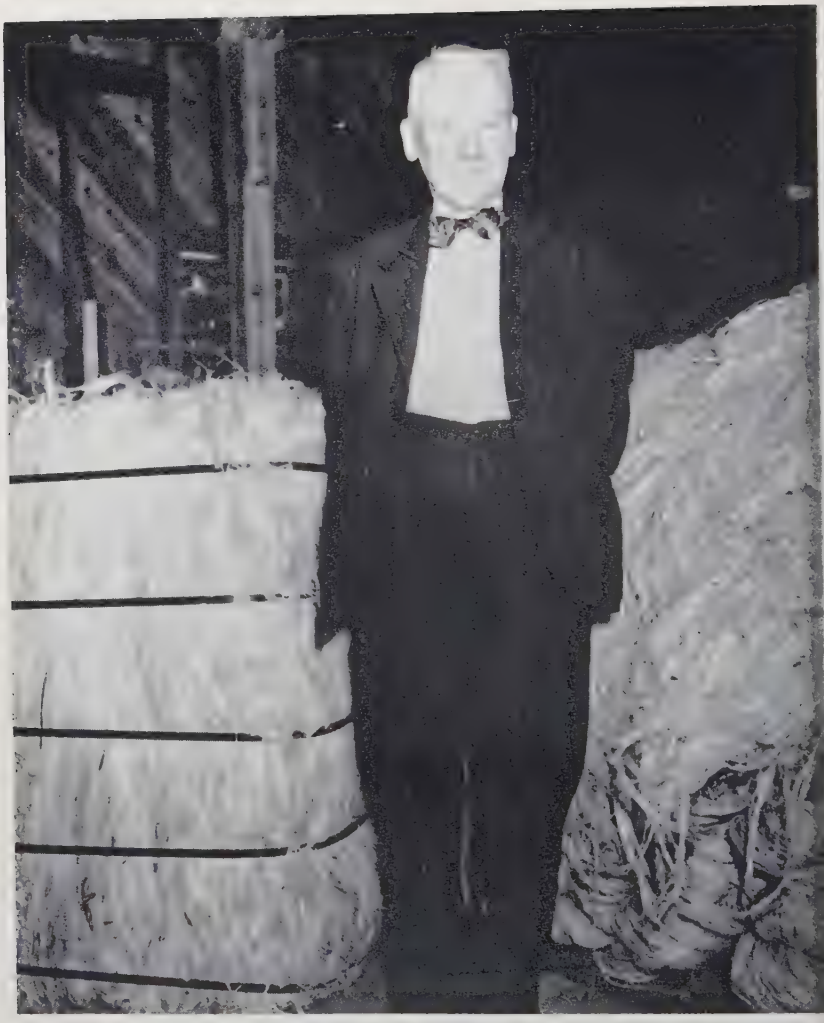

Mr. Frederick Mertz who, as Chief Engineer of Krupp's Fiber Division for mor than 50 years, made many improvements in the Corona-type decorticator. It was h who developed the angled drum approach which first appeared in his Krupp Viktor In response to a request for a brief history of the development of the Corona Decorti cator he very kindly sent us pages 57-60 from the *Sisal Review* for August, 1938 which are reproduced on the pages that follow (239 - 242). As a background for his photograph are to be observed bales of kenaf fiber mechanically decorticated by a Mohegan Corona in the mill of the American Kenaf and Fiber Corporation, Bell Glad.

THE HISTORY OF THE CORONA DECORTICATOR

The development and history of the sisal industry in East Africa is connected very closely with the development of the Corona Decorticator of Messrs. Fried. Krupp Grusonwerk A-G., Magdeburg, as is also the rise of the sisal industry in the Dutch East Indies.

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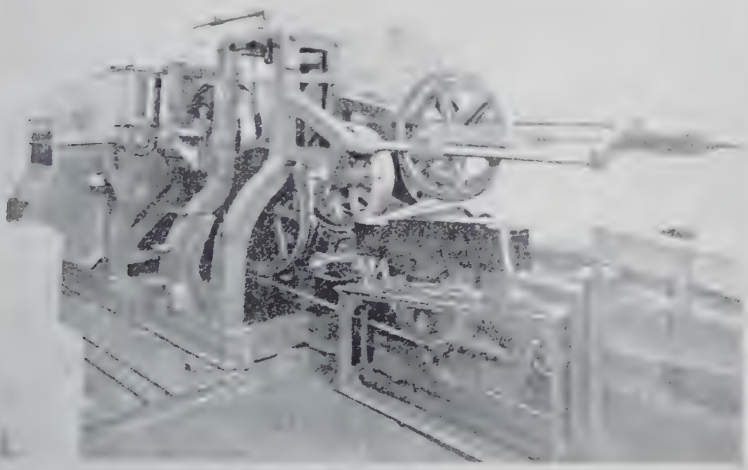

THE HISTORY OF THE CORONA

II. Mr. Hubert J. Boeken.

III. Machine which served for [illegible]

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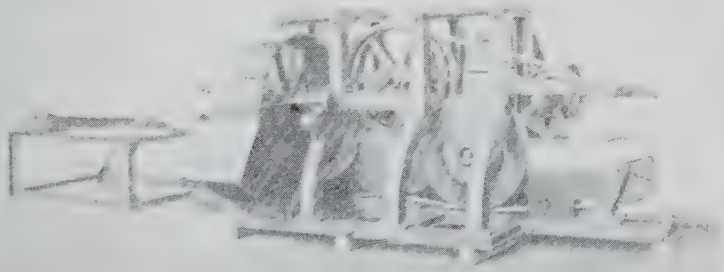

HISTORY OF THE CORONA DECORTICATOR. (contd.)

VI. The late Mr Ebeling.

Mr Guenther

Containers in which Fibre Recovered was originally washed. The Fibre Recovered is now washed in the Decorticator itself.

OTHER EQUIPMENT OF NOTE FOR THE HARVESTING AND PROCESSING OF BAST FIBER CROPS THAT THAT HAS BEEN STUDIED RECENTLY

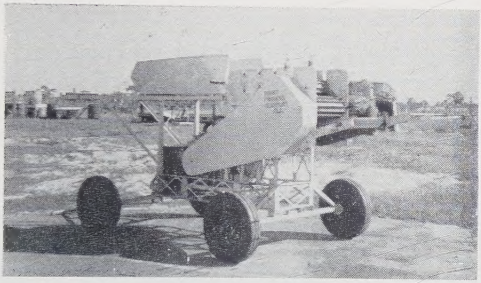

Figure 1. Hand-fed ribboning machine developed by Mr. Charles R. Short of Clermont, Florida, has high-speed rolls and clears the ribbons rapidly with virtually no fiber loss.

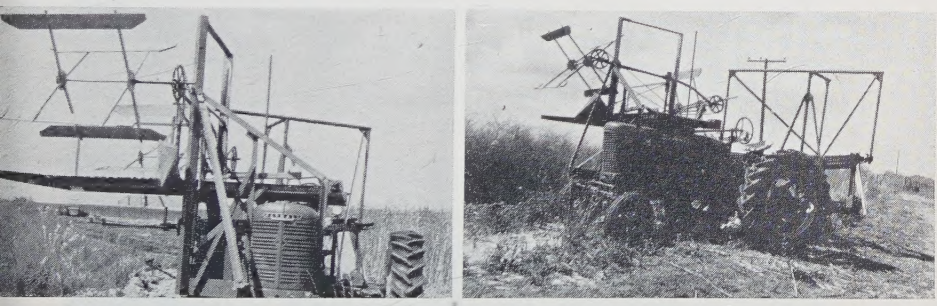

Figure 2. Henriquez harvester showing (front view) topping attachment mounted in an adjustable frame in front of and on side of tractor. The reel forces the tops of the kenaf plants into the horizontal conveyor which carried them over the top of the tractor and drops them at the side. The gathering and grip conveyor (side view) is shown at the rear of the tractor. This unit is mounted on a standard mowing machine. The harvested stems are deposited in a continuous windrow on left of the tractor.

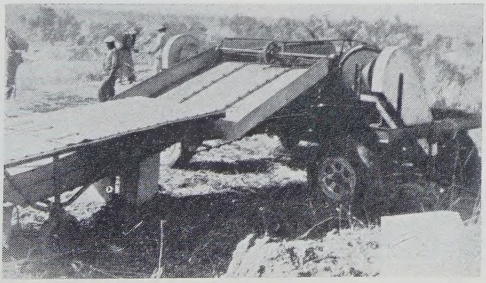

Figure 3. Henriquez ribboner, "V" pattern, double drum type with feed table and single-grip conveyor which forces the stalks into and removes the ribbons from the opposed "bottom" and "tip" drum-type beaters. The angled arrangement of the drums gives a progressive cleaning towards the center of the stems. Unfortunately the central section of the stalks held continuously within the gripping device is not cleaned in the present development of the unit.

THE FIRST MEETING OF THE U.S.D.A. KENAF FIBER GRADING COMMITTEE

1951

The first meeting of the U.S.D.A. Fiber Grading or Typing Committee for kenaf was held at the Everglades Experiment Station on the morning of November 1st and continued through the entire day with a special field trip to the mill of the American Kenaf and Fiber Corporation in the afternoon.

A good supply of fiber representing the full scale of quality being produced at the time was made available for study. Four tentative types or grades were set up during the day subject to change as the study continued on into the future. Several sets of samples representing all four grades were prepared but a sufficient amount of the top grade was not found to bale and find a place in commercial handling. As a result of this fact at a later meeting of the Grading Committee (Nov. 21, 1951) these three grades, Nos. 2, 3 and 4 were finalized for the 1951 crop and numbered 1, 2 and 3 but still represented only Medium, Fair and Low types or grades of fiber, respectively.

The committee was continued with the substitution on it of Mr. Ralph J. Blank, Vice President, American Kenaf Fiber Corporation for the

Figure 1. Members of the Fiber Grading Committee from left to right, with E. D. Bell, Deputy Director, Cotton Branch of the Production and Marketing Administration, U.S.D.A., Washington, at the far right: Walter R. Guthrie, Lehigh Spinning Company, Allentown, Pa.; Elton G. Nelson, U.S.D.A., Beltsville, Md.; H. C. Slade, Standardization and Appeals Section, Cotton Branch, P. & M. A., U.S.D.A., Washington; Alexander L. Guterma, American Kenaf and Fiber Corp., New York City.

President of that Corporation, Mr. A. L. Guterma. The only known source of official information on the deliberations of the Committee is the files of the Cotton Branch, P. and M. A., U. S. Dept. Agriculture, Mr. E. D. Bell, Deputy Chief.

Figure 2. The Fiber Grading Committee in general session, left to right: R. A. Colyer, Australia; J. M. Dempsey, Canal Point; R. J. Blank, West Palm Beach; Geo. R. Boyd, U.S.D.A., Washington, D. C.; A. L. Guterma, New York City; Elton G. Nelson, U.S.D.A., Beltsville; Walter R. Guthrie, Allentown, Pa.; H. C. Slade, U.S.D.A., Washington, D. C.; Clovis D. Walker, U.S.D.A., Washington, D. C.; Wilson C. Tucker, U.S.D.A., Washington, D. C.; S. M. Kimball, U.S.D.A., Atlanta, Ga.; E. D. Bell, U.S.D.A., Washington, D. C.

Figure 3. Members of the Fiber Grading Committee and others at the plant of the American Kenaf and Fiber Corporation's plantation southeast of Belle Glade, left to right: Dr. A. G. Peterson, Munitions Board; Dr. C. H. Schoffstall, National Production Board; Mr. H. C. Slade, U.S.D.A.; Mr. E. D. Bell (head turned), U.S.D.A.; Mr. Walter Guthrie, Allentown, Pa.; Mr. E. G. Nelson, U.S.D.A.; Mr. Wilson C. Tucker, U.S.D.A.; Mr. A. L. Guterma, President of the American Kenaf and Fiber Corporation.